ANALYSIS OF FACTORS AFFECTING THE POSTHARVEST LOSS IN THE LITCHI VALUE CHAIN, DINAJPUR, BANGLADESH

A THESIS

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Master of Agricultural Production Chain Management

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A research thesis submitted to Van Hall Larenstein University of Applied Sciences in partial fulfilment of the requirements for the degree of Master in Agricultural Production Chain Management, Specialisation Horticultural Chains

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The Author

Dedicated to

My grandfather, *Narayan Chandra Mandal*

you will always be here in my heart, guiding me towards the light

Contents

List of tables

List of figures

List of annexes

List of acronyms

BARI	Bangladesh Agricultural Research Institute
BRAC	Bangladesh Rural Advancement Committee
DAE	Department of Agricultural Extension
DAM	Department Agricultural Marketing
AIS	Department of Agricultural Information Service
GAP	Good Agricultural Practices
GO	Government Organisation
NGO	Non-Governmental Organisation
SAARC	South Asian Association for Regional Cooperation
HSTU	Hajee Mohammad Danesh Science and Technology University
LDPE	Low-density polyethylene
MAP	Modified atmosphere packaging
M. tons	Metric tonnes
DAP	Di-ammonium Phosphate
MOP	Muriate of Potash
GI	Geographical Indication
SPSS	Statistical Package for the Social Sciences
B:C	Benefit-Cost Ratio
Tk	Taka
Env.	Environment

Abstract

A study was conducted on the litchi value chain to analyse the factors affecting postharvest loss in Dinajpur, Bangladesh to suggest the Department of Horticulture possible recommendation. This study was remotely conducted online due to the COVID-19 situation during the research period and with the help of a research assistant in Dinajpur, Bangladesh questionnaire data was collected. This study had the objectives to illustrate the dynamics of the litchi value chain and analyse the factors affecting the postharvest loss among different litchi producer groups in the litchi value chain, Dinajpur, Bangladesh. For visualising the value chain and the opportunities and constraints of litchi in Dinajpur, key informants were interviewed. Moreover, a semi-structured questionnaire was used to analyse the factors affecting postharvest loss in the litchi chain. In the litchi chain, producers, Aratdar, Pikar, retailers and consumers are linked in a chain to supply litchi. This chain is male-dominated in terms of activities, access and control, where women are involved in sorting grading and packaging. Litchi in Dinajpur has specific qualifications for its climatic condition, which is considered a major strength. On the other hand, damage from the litchi fruit borer, scarcity of quality seedlings, the irregular bearing habit of litchi tree, fruit and flower dropping are the major weaknesses. However, high demand with a high price for litchi from Dinajpur is a major opportunity for the actors. Recent changes in day and night temperature may be becoming a threat for the litchi tree to achieve quality production. Regarding these constraints, litchi producers are failing to meet the consumers demand in the chain. Litchi producers hold 90.90% value share, where Pikar and retailers hold 4.55% value share each. The practice of preharvest technology was found similar in most of the farms, where pesticides, Calcium and Boron spray and use of plant growth regulators are mostly selected. On the other hand, it was stated that litchi was harvested by climbing the tree or hand picking. Most of the producers used bamboo baskets and plastic crates with leaf or paper filling material to pack litchi. There is no significant difference in harvesting and packaging among different farm sizes. Litchi was transported to the Arat using the auto van, although truck and pick up trucks were used for long distances. According to the study, producers were affected by 13.88% to 19.20% loss per 1000 litchi and 29.98% t 34.60% loss per 1000 Tk (9.92 €). Most of the respondents were having enough finance for reinvestment, preharvest and postharvest technology. There is a significant difference in the investment of pre and postharvest technology by the producers from different farm sizes. Furthermore, litchi producers managed their waste by burning, where they stated they have knowledge over agrochemicals rules and regulation, biodiversity and environment-friendly packaging. However, litchi producers ranked their knowledge 4 out of 10 scales, which may not be significant for conducting environment-friendly production.

Chapter 1
Introduction

1.1 Background of the study

Litchi (*Litchi chinensis*) is a non-climacteric fruit from the Sapindaceae family, is well known to its consumer for juiciness, slightly sour-sweet taste and attractive colour (Wills *et al.*, 2004). With high water content (76-91%) litchi fruit is rich in bioactive compounds, minerals, vitamins, sugars, fats, protein and flavouring components (Pareek, 2016). Litchi is grown in Dinajpur, Chittagong, Khagrachhari, Rangamati, Kishorganj, Jashore, Mymensing, Natore and many more locations. In Dinajpur, around 424.11 ha area is under litchi cultivation, where total production is 10625 metric tons. Akter *et al.* (2016) conducted a study in the Dinajpur region and concluded that the Benefit-cost ratio is 1.93 Tk (0.019 Euro) and litchi cultivation is profitable.

Litchi has a short postharvest life, where the bright red pericarp turns brown and micro-cracking can be seen on litchi (Sivakumar *et al.,* 2007). However, the adoption rate of postharvest technologies of the farmers is not noticeable. Consequently, the food quality reduces from the time of harvesting and consumers do not get the required quality litchi. Major postharvest loss (16%) in litchi is recorded by Molla *et al.* (2010), although there is no recent study in the Dinajpur region. Litchi has high demand in the market due to its unique taste. Litchi season is only for 60 days per year, however, there is a shortage in litchi supply (Siddiqui, 2002). On the other hand, the demand for processed litchi is rising and according to a report, it will reach 25% in near future (Arfin *et al.*, 2017).

1.2 Research problem

Litchi is a non-climacteric fruit and has a short postharvest life, however, postharvest technology among the litchi producers is not practised after the harvest to increase postharvest life. Consequently, loss in harvested fresh fruit and shortage in supply is happening. The department of horticulture, Hajee Mohammad Danesh Science and Technology University is doing research for the farmers in the Dinajpur region for more than 20 years. The study is required to analyse the dynamics of the litchi value chain in Dinajpur, which will help the commissioner of the Department of Horticulture to visualize the linkage and roles of actors and supporters. It is noted that to research's best knowledge that there is no existing research to describe the postharvest loss factors in Dinajpur specifically. Reasons for these problems can be the research gap in the litchi chain, no value chain expert in litchi and inefficient literature available for this crop. In contrast, proper causes of the problem need to explore through this study. Hence, this research problem is hindering the development of applied research activities to mitigate the postharvest issues in the litchi value chain, Dinajpur to increase the supply in the market.

Regarding this problem statement, proper knowledge of actors and supporters in the chain and their function is essential to visualise the value chain. Moreover, analysis of the factors affecting the postharvest loss is required for the problem owner Department of Horticulture, Hajee Mohammad Danesh Science and Technology University to find the root causes of postharvest loss for formulating research projects to increase the market supply of litchi.

1.3 Objective

- To illustrate the dynamics of the litchi value chain in Dinajpur, Bangladesh
- To analyse the factors affecting the postharvest loss among different litchi producer groups in the litchi value chain, Dinajpur

1.4 Main research question

1. What are the dynamics of the litchi value chain in Dinajpur, Bangladesh?
2. What are the factors affecting postharvest life in the litchi chain among different litchi producers (Small, medium and large)?

1.5 Sub-questions

1) What are the dynamics of the litchi value chain in Dinajpur, Bangladesh?
   a) Who are the involved stakeholders and their role in the litchi value chain?
   b) What are the gender aspects including activity, access and control in the litchi value chain?
   c) What are the opportunities and constraints in the litchi value chain?
   d) What is the value share distribution of stakeholders in the litchi value chain?
2) What are the factors affecting postharvest life in the litchi chain among different litchi producers (Small, medium and large)?
   a) What is the difference in preharvest and postharvest technology used among litchi producers?
   b) What is the current postharvest loss of litchi in the chain?
   c) What are the barriers to use the preharvest and postharvest technologies by the different litchi producer groups?
   d) What is the environmental and economic impact of preharvest and postharvest technology?

Chapter 2
Literature review

A literature review of previous findings is discussed in this chapter to find the existing literature to formulate the new conceptual framework. This conceptual framework is helpful to find the answer to the research questions. Different findings on the litchi value chain are presented in the following sections.

2.1 Litchi production in Bangladesh

Litchi is an attractive red fruit, which has high market demand, however, supply is not sufficient. According to the agricultural survey report of 2017 litchi production is presented in the following table 1 for all divisions.

Table 1 Litchi production in Bangladesh in year 2016-17

Division	Area under garden (Ha)	Production of inside garden (M. tons)	Production of outside garden (M. tons)	Total production of inside & outside garden (M. tons)
Barishal	0.40	3	750	753
Chittagang	326.18	2486	4698	7184
Dhaka	50.18	1150	8394	9544
Khulna	449.20	5410	8102	13512
Mymensing	8.09	379	10242	10621
Rajshahi	2137.15	7809	17853	25662
Rangpur	793.18	10145	10820	20965
Sylhet	17.80	166	1890	2056
Total	**2887.84**	**27548**	**62749**	**90297**

Source: BBS, 2018

Uddin *et al.* (2016) conducted a study in 304 hectares area for litchi orchard in Chittagong region and observed significant positive growth in orchard land size over 1993/94 to 2009/10 which is 12.18%. The author noted the adoption of improved variety and good management practices by the farmers.

Akter *et al.* (2015) performed research with 60 litchi growers in the Dinajpur region of Bangladesh. In her study, she recorded data based on the growth stage of litchi and prepared a cost of production calculation. In contrast, she reported that litchi production is a highly profitable sector with Euro 4278.89 per hectare net return. Furthermore, she noted in her study that the profitability of litchi depends on the weather and age of the plant.

Siddiqui (2002) reported that very good quality litchi grows in the Chittagong hill district area, but the rate of expansion is extremely slow, which may be due to prevailing social unrest and difficulty in establishing new orchards.

2.2 Litchi producers in Bangladesh

According to the Department of Agricultural Extension, Dinajpur, there are 624943 farmers family in this area where 12238 hectares is under permanent fruit orchards. In case of litchi 1500 hectare is under litchi cultivation, where each hectare contains 247 litchi trees (DAE, 2021). However, there is no reliable specific data for total litchi farmers in Dinajpur.

A research study conducted by Hossain *et al.* (2017) in the hilly region of Bangladesh with 2050 farmers and 749 traders observed postharvest losses in litchi fruits. It was stated that at the farmers and traders level amount of postharvest loss is 165 kg/metric tons (17%). However, the cause of

postharvest loss was different at the traders and farmers' levels. In farmers level study reported that major loss of fruit is caused by monkeys, insects, bats and squirrels. On the other hand, the transportation facility caused significant damage to fruits at the traders' level.

2.3 Value chain

The value chain analysis concept is new in Bangladesh and there is a lack of value chain experts in this field. Although there are several studies done for the litchi chain, there is no chain analysis in Dinajpur.

A study conducted by Dewan *et al.* (2015) on the different market channels including litchi, found that two types of problems in production and market in the Khagrachhari district. In the production problem, it was observed that disease was affecting the yield of the fruits, whereas storage and processing facilities were not available in that region which is causing a major marketing problem. Furthermore, four types of intermediaries like Bepari, Faria, wholesaler and retailer were reported to be involved in the fruit market channel.

In a report, Hassan (2014) mentioned that the horticulture chain in Bangladesh has major concerns like heavy metal contamination from agrochemicals and microbial contamination. These issues are affecting the postharvest life of the fruits and increasing health risks to the consumers. However, with the new Food Safety Act, it was supposed to be controlled, there is no awareness among the stakeholders to act for food safety. The author stated that with the help of governmental and non-governmental organisations all the stakeholders need to be trained to ensure food safety in the horticultural chain.

In another study, Dewan *et al.* (2014) reported that there are six supply chains involved in the fruit market, where the litchi chain from grower to consumer ranked highest (34.23%) in Khagrachhari. Furthermore, it was noted that major constraints in these chains were lack of training facility for farmers, postharvest loss, lack of processing centre and credit unavailability.

2.4 Gender

In the litchi value chain, the function of gender is unknown and it was not recorded in any literature. However, gender role is important in terms of value chain perspective as empowered women can create better business opportunities for women which can reduce the poverty among farmers (KIT *et al.,* 2012). The Harvard analytical tool, also known as the gender role framework, can be a critical way to analyse the activity, access and control of resources in the litchi value chain (Ludgate, 2016). This can lead to gender empowered value chain development to increase both social and economic position.

2.5 Preharvest management

Multiple preharvest management is done to increase fruit yield and quality. Fruit orientation in the harvesting of different litchi varieties *viz.* Deshi, Bedana, Bombai, Mojaffori and Chaina-3 was studied by Rahman *et al.* (2010). In this study it was noted that fruit in the lower half portion of the tree contains more flesh and pericarp in weight whereas, the upper portion fruit contains more vitamin C, pH, non-reducing sugar and stone weight. It is recommended that harvesting of litchi should be done from the lower half portion and will be continued to the upper half portion.

A study by Mitra and Pathak (2008) on litchi production in the Asia-Pacific region stated that Lepidopterous fruit borers are major concerning pest for litchi damaging the fruits. It punctured the peduncle in the developing fruit, where the larva starts to grow. The larva damages the fruit and causing early dropping of fruit. Litchi producers in Asian countries use a huge amount of pesticides to control this pest.

Litchi tree needs pruning to maintain C: N ratio to produce better yield next year. According to Siddiqui (2002), litchi trees are pruned after the harvest and its pruned to maintain the size and shape of the

tree. Heavy pruning is avoided in litchi trees. Moreover, netting on the tree canopy is done during fruit formation to reduce the damage to the fruits due to bats. Litchi orchards have laboured to make noises with metal cans and sheets to prevent the bats to eat them. However, there is no knowledge of using fruit bagging on litchi fruits to maintain quality. In the Department of Horticulture, fruit bagging was used in a project to evaluate the preharvest treatment on fruit quality. There is a need for more study to explore the preharvest treatments among farmers in litchi orchards.

2.6 Postharvest management

Postharvest technology is necessary to increase the postharvest life and maintain the quality of the fresh produce, however, it is not practised among the stakeholders in Bangladesh. Reasons were not analysed by the researchers. In figure 1, it can be seen that litchi is being sorted by labour without any postharvest technology usage. However, studies were done to introduce various effective postharvest technology.

Figure 1 Litchi sorting after harvesting

Source: Author, 2021

For increasing the postharvest life of litchi, Talukder *et al.* (2020), conducted research to find the best solution to reduce the postharvest loss during transportation. In his study, he observed that 75 µm polypropylene bag packaging at 4 °C temperature extended the postharvest life of litchi fruit up to 23.33 days, where litchi without any packaging lasted for 3 days. Furthermore, in the case of quality parameters like titratable acidity, vitamin C, total soluble solids, disease incidence and total weight loss the same treatment performed better than others.

Mehebub *et al.* (2019) conducted an experiment on litchi with foliar application of chitosan for observing the quality improvement. It was noted that there was no significant change in terms of length, weight, flavonoids, phenolic compounds and ascorbic acid, however, antioxidants and antioxidants activities were increased in treated litchis. Furthermore, the author recommended chitosan spray for increasing litchi quality.

In a study of the packaging system for litchi, Purbey *et al.* (2019) stated that delicate fruit like litchi needs advanced packaging with a modified atmosphere, where a wireless sensor, radio-frequency identification can revolutionise the packaging system to increase postharvest life. Recently, actors in the litchi chain are moving towards packaging with corrugated fibre board boxes for better quality management.

Kumar and Kumar (2018) conducted an analysis of different market channels of litchi in Bihar, India and found major marketing constraints in the chain as there is no cold chain present. It is noted that missing cold storage facilities, transportation problems and price fluctuation causing major postharvest loss of litchi.

A recent study by Mahmood *et al.* (2017) from the Department of Horticulture reported that pericarp of litchi started to be brown in the traditional postharvest method (using bamboo bin) after 6 days whereas usages of LDPE bags performed better with 9 days of postharvest life.

In India, Kumar *et al.* (2016) studied two different packaging systems corrugated fibreboard box and wooden box pack for litchi transportation. It was observed that corrugated fibreboard boxes performed better than wooden box and it was recommended to the stakeholders to reduce the common postharvest symptoms like pericarp browning, weight loss and microorganism invasion.

Nath *et al.* (2016) stated in an article based on challenges and opportunities that the absence of a cool chain in the value chain of litchi affecting the postharvest life. Moreover, the lack of processing of this product can increase the postharvest life. Therefore, the value addition of this product can benefit the actors involved.

In a published report by SAARC (2014) horticultural value chains in Bangladesh was analysed. It is stated that there is cold storage facility available for only potato crops, however, no recorded cold storage, defective packaging, transportation system, no cold chain and no market information among the actors are the main reasons for postharvest loss for horticultural crops.

With structured questionnaires and focus groups, discussion Rahim *et al.* (2013) analysed the fruit value chain to determine the factors affecting the quality improvement. It is noted that in the fruit value chain there were insufficient processing capacity, cold storage and transportation problem is causing the main postharvest losses in the fruit chain. It is constraining the value chain in value addition and major economic loss in the chain is unavoidable.

Modified atmosphere packaging (MAP) was used in an experiment by Mangaraj *et al.* (2012) for litchi crops and it was observed that MAP reduced the pathological and metabolic degradation of fruit. Furthermore, the colour of the fruit was maintained in the experiment. Therefore, it was recommended to the stakeholders in the chain to use MAP where no cold storage or cold chain is available.

An experiment was done by Aklimuzzaman *et al.* (2011) with three litchi varieties Bombai, Bedana and China 3, where it was observed that the postharvest life of these varieties is as follows Bedana (3.75 days), Bombai (2.08 days) and China 3 (3.07 days). It can be noted that these major varieties of litchi have a more or less similar shelf life and it is not significant enough to reduce postharvest loss. Moreover, it was shown that vitamin C, moisture content, weight, dry weight was decreasing where pulp pH was increasing for each variety. Pericarp browning was seen in the case of each variety which reduces the attractiveness of the fruit to the consumer.

Mitra and Pathak (2008) reported that in Asia pacific region litchi productions has some major constraints in the postharvest sector as there is no cold chain available. The use of sulphur dioxide fumigation can result in good pericarp colour, however, if the dose is not properly regulated it can alter the tastes. It was stated in the article that litchi fruit suffers from fruit cracking due to calcium

deficiency and drought and high temperature. This is a major problem for yield loss. This condition is also observed in Dinajpur as this region has drought conditions with high temperatures.

Reza *et al.* (2007) conducted a field experiment on litchi in Dinajpur to assess the effect of fertiliser and irrigation on fruit quality and yield. It was observed that the highest dose of fertiliser (1.5 kg N, 1.32 kg P and 1.25 kg K) and two irrigation in the litchi orchard resulted in the highest yield and fruit quality. It was also noted that fruit quality was assessed by an expert panel for scoring.

Siddiqui (2002) stated in a report that litchi has high demand in Bangladesh, however, due to lack of supply it often fails to meet the customer demand. The author stated several reasons for this vulnerability in the chain is caused because litchi with traditional basket packaging can only last for 48 hours. Moreover, there is no storage facility for this crop to extend the postharvest life. It is quickly transferred in the chain to reduce the loss. Nevertheless, the transportation facilities are not adequate enough to maintain the quality of litchi. Therefore, litchi crop is losing the local and export market.

2.7 Economic impact

As the season is very short for the litchi chain, the economic impact is sensitive to analyse. It was observed by the researcher that any minor cost is avoided in the chain to get more profit. Assessment of the economic impact of the cost of the litchi pre and postharvest technology needed for getting an overview of the cost that litchi producers can afford. This information will be valuable to develop new technology for the farmer which can be adopted easily to maintain the quality of litchi in the chain.

2.8 Environmental impact

The use of agrochemicals in the litchi orchard is common practice and the following of the safety regulation is not monitored and practised. This observation was done by the researcher during his work. However, it is required to study the environmental impact of current postharvest technology usage.

In the litchi orchards, there were incidents of deaths of children by acute encephalitis syndrome. This alarming situation was studied by Islam *et al.* (2017) and they reported that children were not affected by the acute encephalitis syndrome because of eating the litchi fruit, however, exposure to the agrochemicals in the litchi orchard is the main reason for the disease outbreak among children. This study reveals the dangerous use of agrochemicals in the litchi orchards can be fatal to human life.

2.9 Conceptual framework

With the literature review following conceptual framework is developed and presented in figure 2.

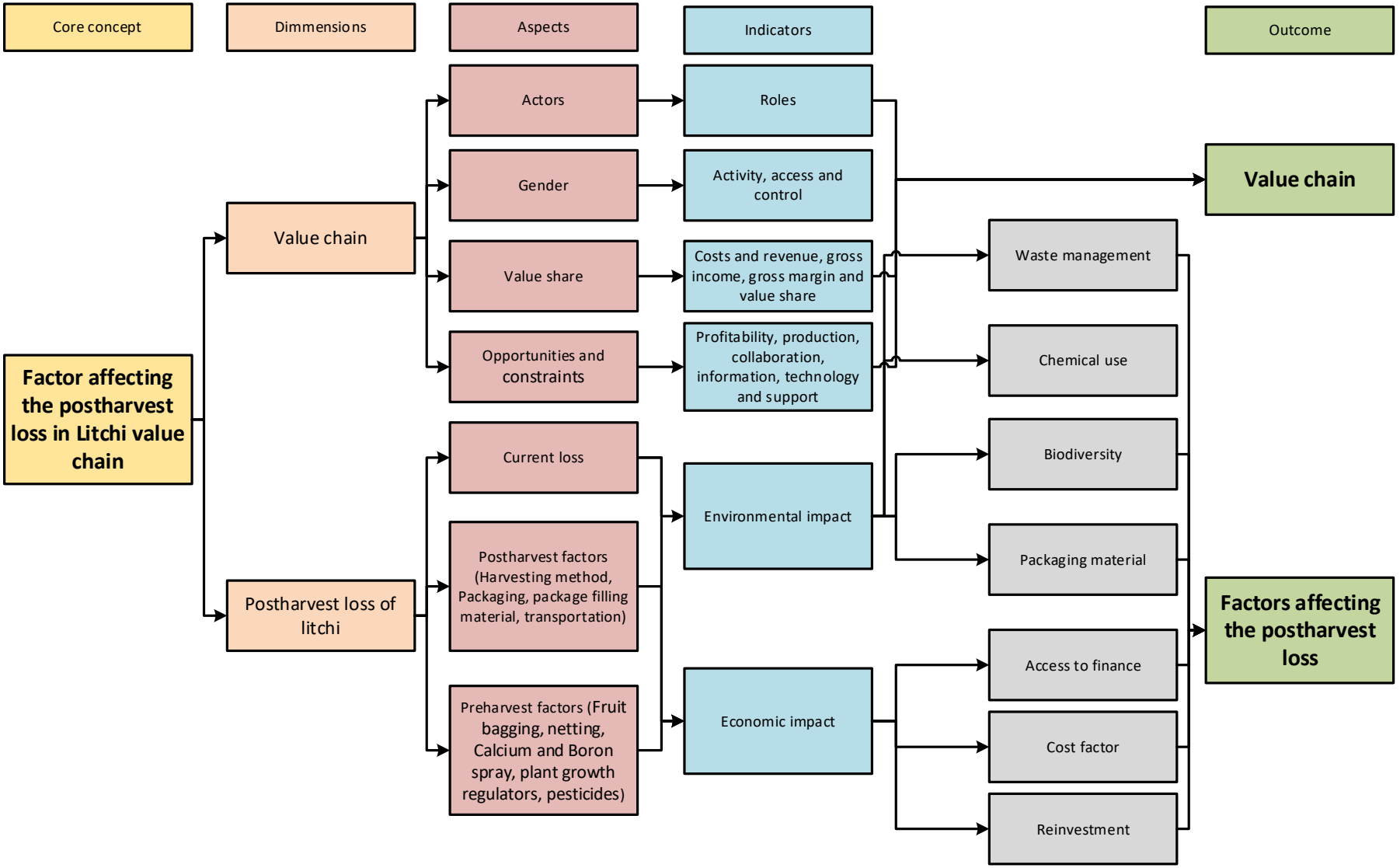


Figure 2 Conceptual framework
Source: Author, 2021

Chapter 3
Methodology

Research methodology is described in this chapter for the collection of data. Furthermore, data processing and analysing to write a scientific report is further explained. Due to Covid-19, several limitations might arise and strategies to mitigate these issues included. The following sections are made to clarify the methodology step by step.

3.1 Study area

Dinajpur, Bangladesh is situated in the Rangpur division. The elevation height of this area is 34-36 meters from sea level. This region is situated in 25°10' and 26°04' north latitudes and 88°23' and 89°18' east longitudes (Figure 3). Tropical wet and dry climatic condition is the criteria of this region (Banglapedia, 2021). This districts' annual average temperature is 25°C. this region is located in AEZ-3: Tista Meander Floodplain, where areas have broad floodplain ridges and almost level basins. Total 424.11 ha area is under Litchi cultivation and 10625 metric ton was the annual production in the 2016-2017 year (BBS, 2018). In Dinajpur district, the Auliapur union was selected for data collection as this region is popular for its litchi orchards.

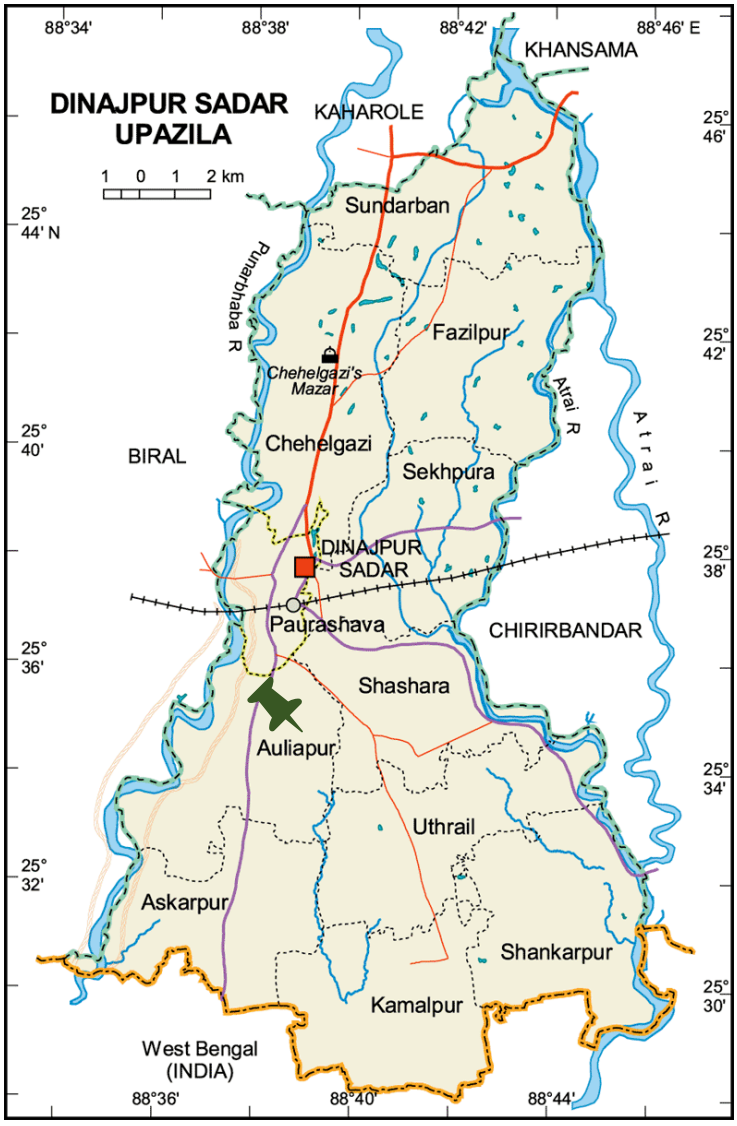


Figure 3 Dinajpur district

Source: Banglapedia, 2021

3.2 Sampling

In the study area, litchi producers were selected from the study area with a simple random selection method (Blaxter *et al.,* 2010). From the Auliapur region randomly litchi producers of three different groups based on farm size were selected for this survey to get representative data for statistical analysis (Table 2). With the researcher field observation in his research project, a greater number of small orchards were present than the larger and medium orchards. Therefore, 50% of the respondents were from the small orchards, where 30% and 20 % are from the medium and large orchards respectively. Data for a different group of farmers was not available to categorise the farmers in this area. Categorisation of litchi producers helped to find the differences in the findings according to orchard size. However, the following grouping of litchi producers was proposed to compare the findings.

Table 2 Grouping of litchi producers according to orchard size

Group	Orchard size (Hectare)	Sample size
Small orchard	Less than 0.50	25 (50%)
Medium orchard	0.50-0.75	15 (30%)
Large orchard	Greater than 0.75	10 (20%)
Total		**50 (100%)**

Source: Author, 2021

3.3 Research strategy

3.3.1 Starting of the research

With the research proposal, a study was conducted online in the Netherlands. According to Worldometer (2021) data, 2,576 new cases of COVID-19 and 40 new death was recorded on 10 June 2021. With this rising COVID-19 situation in Bangladesh, where it was difficult to conduct the interview and survey safely. Moreover, government rules regarding lockdown were tightening in Bangladesh, which limited the movement of the researcher in the study area. Therefore, the online approach was the best way to collect the data from the respondents. Interviews were conducted online and with the help of a fellow colleague in the Department of Horticulture Abdullah Al Mahmud, semi-structured questionnaires were sent to the respondents and data was gathered (Table 3). As my colleague was working in the study area, it was easier for him to collect data immediately. After that data was sent to me in the Netherlands through the online medium like OneDrive, google drive or email.

Table 3 Data collection method for the research

Main questions	Sub questions	Source of information	Data collection method	Output
1. What are the dynamics of the litchi value chain in Dinajpur, Bangladesh?	a) Who are the involved stakeholders and their role in the litchi value chain? b) What are the gender aspects including activity, access and control in the litchi value chain?	• HSTU • HORTEX Foundation • Bangladesh Agricultural Research Institute (BARI) • Department of Agricultural Extension (DAE)	**• Literature review** **• Semi-structured interview**	**Value chain**

	c) What are the opportunities and constraints in the litchi value chain? d) What is the value share distribution of stakeholders in the litchi value chain?	• Department of Agricultural Marketing • Department of Agricultural Information • PRAN Food Ltd • Alor Path e Aso Jubok • Traders (3) • Bank • BRAC • Litchi producers (6)		
2. What are the factors affecting postharvest life in the litchi chain among different litchi producers (Small, medium and large)?	a) What is the difference in preharvest and postharvest technology used among litchi producers? b) What is the current postharvest loss of litchi in the chain? c) What are the barriers to use the preharvest and postharvest technologies by the different litchi producer groups? d) What is the environmental and economic impact of preharvest and postharvest technology?	• Litchi producers (Among 3 groups of litchi producers; in total: 50)	• **Semi-structure questionnaire**	**Factors affecting postharvest life**

Source: Author, 2021

3.3.2 Literature review

Reviewing the previous research was done to gather the existing information. The relevant information and the findings from this study were used to present the findings. However, it was noted that lack of research in the litchi value chain was a prominent factor, where most of the literature was found older than 5 years. In this circumstance, literature findings from reputed journals were taken to avoid reliability issues and were presented with the findings of the interviews and semi-structured questionnaire. For finding literature Google Scholar, Greeni, Science Direct, Springer, Wageningen Academic Publishers, Wiley online library and CABI Direct database was used.

3.3.3 Interview

Interviewees were selected based on the roles of the actors in the organisations for facilitating this chain with the purposive sampling method. To get an overview of the value chain of litchi and answer research question one, the key informants were selected to interview (Table 4). With the researcher's

experience in research projects on litchi, these key informants were useful to get the required data. Most of the interviewees were directly work in the litchi value chain, Dinajpur. However, BARI, Department of Agricultural Marketing, Department of Agricultural Information, HORTEX Foundation works indirectly in the Litchi chain. A semi-structured questionnaire was prepared for asking questions (Annex 1). This type of question was generate direct answers to the questions and there were possibilities to add more from the respondents. Additionally, follow up questions was asked based on the response. An interview checklist was used in the interview to make sure that the purpose of the interview was fulfilled. All the interviews were conducted online and transcript for further data analysis.

Table 4 List of key informants for interviews

Serial no.	Organisation/ individual	Type of organisation	Role	Number of persons
1.	**Department of Horticulture, Hajee Mohammad Danesh Science and Technology University**	Research university	• Research & education	**1**
2.	**Department of Agricultural Extension, Dinajpur**	Government	• Extension service	**1**
3.	**HORTEX Foundation**	Government	• Extension service	**1**
4.	**Bangladesh Agricultural Research Institute**	Research institution	• Research	**1**
5.	**Department of agricultural marketing**	Government	• Marketing of agricultural products	**1**
6.	**Department of Agricultural Information**	Government	• Providing information in the agricultural value chain	**1**
7.	**Rajshahi Krishi Unnayan Bank**	Government	• Finance	**1**
8.	**PRAN Food Ltd.**	Private	• Food processor	**1**
9.	**BRAC**	NGO	• Training • Extension service	**1**
10.	**Alor Path e Jago Jubok**	Volunteer	• Youth development • Promoting litchi production	**1**
11.	**Litchi producer**	Individual	• Produce litchi • Sell litchi	**6** (Two from three types of producer groups randomly selected)
12.	**Trader**	Individual	• Buy and sell litchi	3
Total				**19**

Source: Author, 2021

3.3.4 Questionnaire

Regarding the knowledge gap in the litchi value chain, semi-structured questions were used to get the necessary information to analyse the factors affecting the postharvest loss among different groups of producers (Annex 2). Semi-structured questionnaire data was generated data to visualise the factors affecting postharvest loss in the chain. A research assistant from the Department of Horticulture helped to collect the data with a questionnaire. The questionnaire and the research objectives were explained to him. The distributed questionnaire was in Bengali and the units were on a local measuring scale. Questionnaires were not sent to the farmers as the research has time limitations, where to get better responses data were collected on-site.

3.3.5 Data analysis

Data were collected to answer the main research questions for achieving the objective. The outline of the data collection with the source was illustrated in table 3.

Qualitative data analysis

Interviews were recorded with the permission of the interviewees and the transcript was prepared from the recordings. Using the tools like stakeholder matrix, Harvard analytical tool, PESTEC, SWOT and value chain all the information were presented. Moreover, the value share of the stakeholders in the chain was presented in the value chain map as overlays and graphs for a clear overview.

Quantitative data analysis

Quantitative data was generated from the semi-structured questionnaire. Firstly, descriptive analysis of the data was done and presented with graphs and tables. Furthermore, the difference among three groups of litchi producers in total 50 respondents was analysed where $P \leq 0.05$ using different statistical tests in SPSS Software version 26. The correlation among different factors in relation to postharvest loss was analysed using Spearman and Pearson correlation test where $P \leq 0.05$.

3.3.6 Writing the thesis report

A research thesis has several parts to work on. While collecting the data, writing of introduction, methodology and literature review was done. Each progress was reviewed for consistency with the research objectives. For necessary direction and guidelines, the thesis supervisor was contacted to discuss the solution to mitigate the issue hindering research progress. Data were organised digitally and regular backup was maintained to prevent accidental data loss during research. Results were written to answer the research questions based on the data analysis. The Result section was sub categorised based on the questions to present the findings. Moreover, graphs and tables were used to illustrate the result. After writing the result section it was sent to the supervisor for guidelines to improve.

The whole research writing was reviewed and corrected before writing the discussion. The research journal was also reviewed to find the consistency level or major changes during the research. With the related literature, the findings were discussed. Conclusion and the recommendation were made in this part, where the main research questions were answered, and feasible recommendations were recommended to the commissioner. Reference sections were maintained using Mendeley Desktop software version 1.19.8 referencing tool, which was used to keep the backup of literature and generate automatic referencing. Last but not least, the documents were submitted for evaluation and defended before the assessors.

3.4 Justification of tools

Multiples tools were used to present the findings from the study. For answering research question one these tools were used to describe the value chain. These tools were described below.

Stakeholder Matrix

From the interview data, all the stakeholder's information was inputted in this tool to represent their chain role and function.

Harvard analytical tool for gender analysis

Gender activity, access and control to resources and benefits were presented in this tool (Annex 3). With the information from the interviewees, this tool was used to visualise the chain position of different gender (Ludgate, 2016).

PESTEC

According to the discussion with interviewees, the different factors affecting this litchi chain were categorised with the help of PESTEC tool. PESTEC tool includes analysis of factors like political, economic, social, technological, environmental and cultural of the chain.

SWOT

SWOT shows the strength, weaknesses, opportunities and threats of a sector. With information from the key informants, SWOT was developed to illustrate the opportunities and constraints of the litchi value chain.

Value chain

After analysing the information from the literature review and the interview, a value chain was presented to visualise the Litchi chain in Dinajpur. The value chain contained the stakeholders, supporters showing their functions. Moreover, overlays from value share analysis and volumes of production were presented in this chain to show the share of each stakeholder.

3.5 Calculation of value share

The value share in the litchi chain was calculated from the data provided by the interviewees. From the interview, data about variable costs and revenue per 1000 litchi was gathered. The following equation was used to calculate the gross income, added value, gross margin and value share (KIT and IIRR, 2008). All the calculations were done in the EURO currency rate on 1 August 2021.

$$Gross\ income = Revenue - Variable\ costs$$

$$Added\ value = Revenue - Previous\ actor's\ revenue$$

$$Gross\ margin = \frac{Gross\ income \times 100}{Revenue}$$

$$Value\ share = \frac{Added\ value \times 100}{Retail\ price}$$

3.6 Limitation of the study

The research was started after the end of the harvesting season of litchi. That may have influenced the data as after the season getting the respondents was difficult as they might move on to another crop. With triangulation with available literature, interviews and survey result, exact data was taken for this research. Furthermore, the previous field experience of the researcher as a research assistant with litchi producers was helpful to deal with the seasonality aspects of this research.

Another rising problem in remote research was raised, when the researcher was not available in the research area to collect data that could defer from actual findings. However, in this research on litchi, the researcher had previous experience working in litchi farms with farmers for research projects. Therefore, the previous observation experience and knowledge helped the researcher to evaluate the

gathered data and eliminate the reliability issues. Furthermore, because of COVID-19 whole country was under strict lockdown during the data collection phase. It made data collection from the farmer and scheduling for interviews difficult. Interviewees or their relatives were directly or indirectly affected by COVID-19 in the research period. It was difficult to get a schedule from a key informant on time. In this remote research, communication problems with the interviewees were a major problem. All the interviewees were reached out with the purpose of research and requested an interview schedule. However, slight overlapping of the scheduling made it possible to finish the data collection on time. Similarly, the research assistant was not able to travel on time due to restrictions, where data collection was delayed a little bit. These delays and difficulties had affected the scheduling of the research. Moreover, the researcher kept a journal and tracked every progress with time. Any changes in the tasks were traced and for solving the issue discussed with the supervisor was made for taking action.

3.7 Research framework

The whole research process is summarised in the research framework (Figure 4). This framework will be followed to conduct the research.

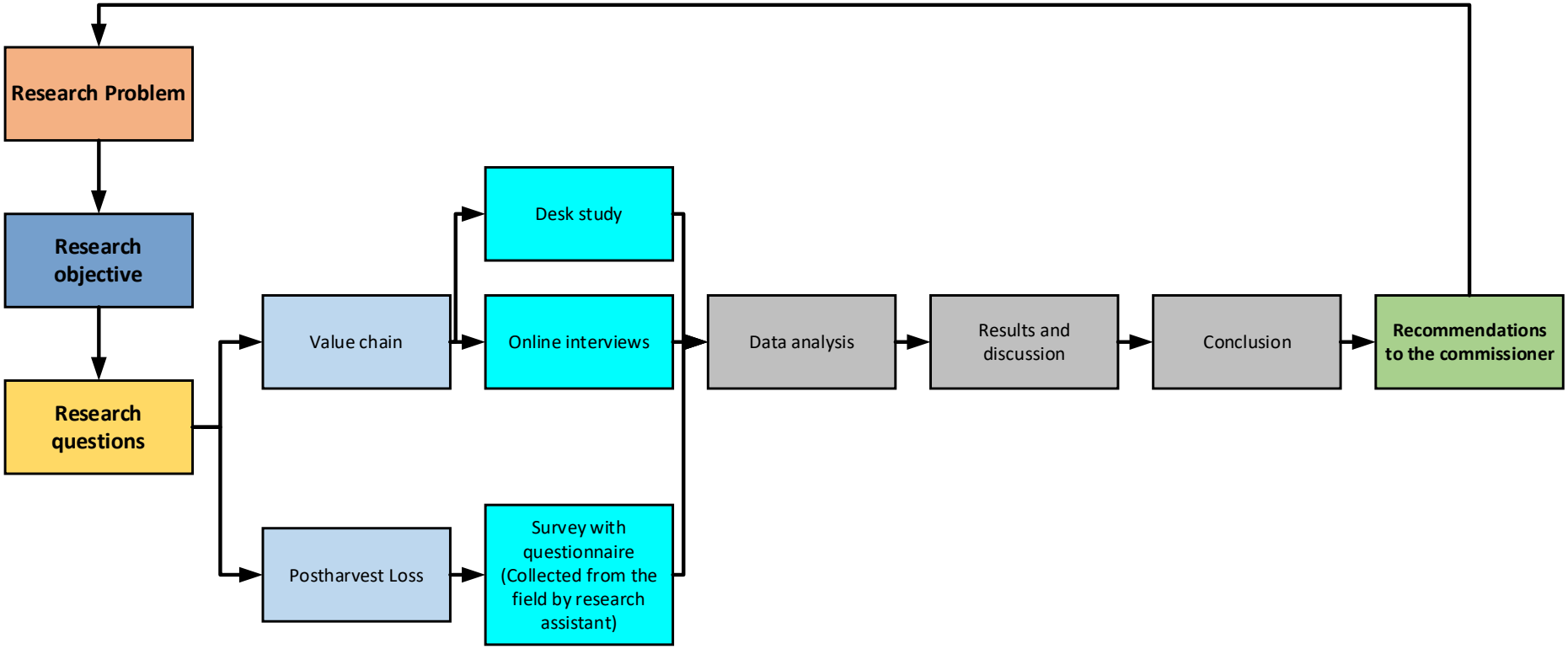


Figure 4 Research framework

Source: Author, 2021

Chapter 4
Results and findings

In this chapter, the findings of this research are presented to answer the research questions according to interview and questionnaire data after analysis. Required additional information is referred at the annex for further clarification.

4.1 Value chain of litchi

From the interview data, actors and their link in the chain is clarified. Department of Agriculture has 19 wings working for the development of agriculture in Bangladesh. However, only a few departments are linked with the Litchi value chain. Personals in the chain help the actors with trading, input supply, research, finances and extension services. In terms of agricultural supplies, litchi producers are mainly dependent on local suppliers. They rely on the advice of the local suppliers for their production practices and their own self experiences. Moreover, the Department of Agricultural Extension helps the farmers with seedlings, plastic crates and trainings, which is not significant enough for the producers. There is an opportunity to finance their activities from the Rajshahi Krishi Unnayan Bank and NGOs, although litchi producers are dependent on their own finance. Litchi producers sell their orchards to the trader for their own year to five years. These traders take care of the farm during the contract period. When litchi is ready for harvest they take it to the Arat (an auction place for litchi), where Aratdar (auctioneer at Arat) takes 50 Tk per 1000 litchi for auction fee and Pikar buys it to sell it to the retailers in a different location. PIkars are the wholesaler who buys litchi from the Aratdar. On the other hand, some Pikar comes to the farm directly buy it from the litchi producer and takes it to their region to sell. For local consumption, local pikar or consumers buys it directly from the orchards. However, local pikar also buys from the auction to sell it in the local market. It was noted that local people demand high-quality litchi directly from the orchard as they prefer the quality of the product. There is no major export line in this value chain, however, export of litchi in minute amount was recorded by the Plant quarantine wing. A processor like PRAN Food Ltd. does not process litchi to make litchi drinks as there is no significant amount of litchi available in the region to meet their processing requirement. Although litchi drinks from PRAN Food Ltd. have a huge export market in India, Nepal, the middle east and other countries. However, honey produced in litchi orchards is becoming popular and has demand in the local and national markets. The Value chain of litchi is visualised in figure 5 and the overlays are presented to illustrate the overall market price fluctuation. Although determining the exact price of litchi is difficult due to different costs of production and market price at different times. Information flow is horizontal and majorly one way from the supporters to the litchi producers

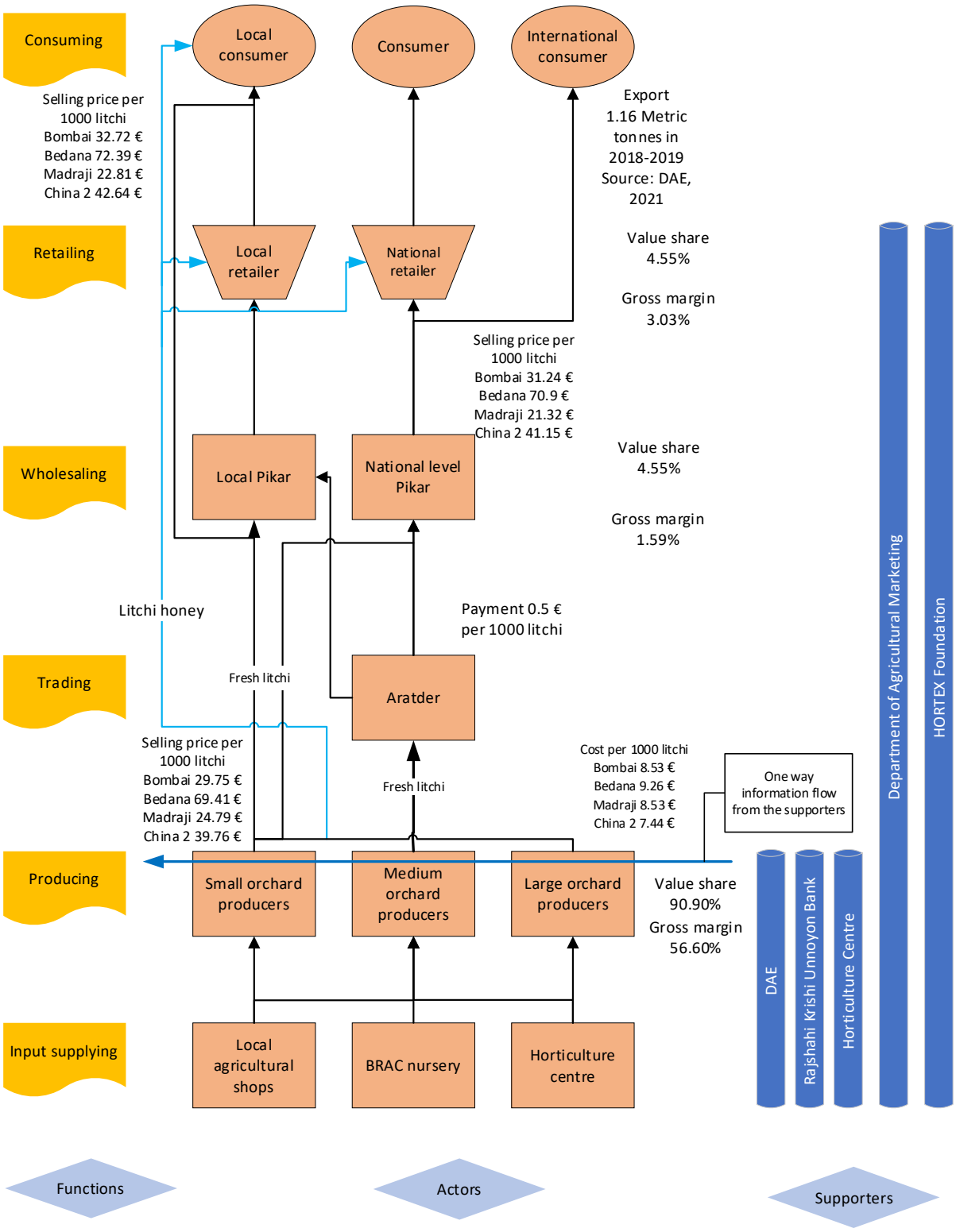


Figure 5 Value chain of litchi in Dinajpur

(Value share and gross margin is calculated for Bombai variety)

Source: Author, 2021

4.2 Role of the stakeholders

From the literature study, there was no evidence on the number of involved stakeholders in the litchi chain. Selected stakeholders were interviewed and key findings were presented in table 5. In the litchi chain, the Department of Horticulture stated its strong position in horticultural research, although it was evident that there is an information gap in the litchi value chain for conducting further research. On the other hand, the Department of Agricultural Extension service provides all kinds of training, workshop and extension service to the farmers, however, in litchi chain there is no training activities. From the statement of the HORTEX foundation, their role is to work on the horticultural supply and value chain, increase the capacity of stakeholders and develop the export potential for horticultural crops. BARI is a major research institute in Bangladesh, reported that they developed litchi varieties BARI Litchu 1, BARI Litchu 2, BARI Lithcu 3, BARI Litchu 4 and BARI Litchu 5 (Azad *et al.,* 2020), worked on litchi value chain analysis of Chittagong district region (Uddin *et al.,* 2016). Moreover, postharvest research is going on for different horticultural crops including litchi. On the contrary, DAE has reported that these BARI Litchu varieties failed to meet the production at field trial at Dinajpur as stated in the report. Therefore, litchi producers did not adopt these varieties.

Figure 6 Litchi selling at Arat in Dinajpur

Source: Author, 2021

Department of Agricultural Marketing is a new wing of the Department of Agriculture in Bangladesh. It is trying to provide market information to the farmers through its website. Furthermore, training on postharvest technology and maintaining marketing channels are major activities. However, it is under process to provide the regional market price of the product instantly to the farmers. Currently, information is provided on-demand basis. In the litchi chain, Arat is the regional market where litchi is sold to Pikar (Figure 6).

Table 5 Stakeholder matrix of the litchi value chain

Function in the chain	Actor	Type of organisation	Features
Supporter	**Department of Horticulture, Hajee Mohammad Danesh Science and Technology University**	Research university	• Research on horticultural crop • Provide agricultural training and services to the farmers through Krishok Seba Kendra at HSTU
Supporting	**Department of Agricultural Extension, Dinajpur**	Government	• Providing extension service • Training • Workshop • Transferring research output to the farmers
Supporting	**HORTEX Foundation**	Government	• Provide training on postharvest technology • Provide storage, packaging and marketing facilities • Promoting horticultural products and create export opportunities • Value chain management
Supporting	**Bangladesh Agricultural Research Institute**	Research institution	• Research on horticultural crop • Technology development
Supporting	**Department of agricultural marketing**	Government	• Provide market information to the farmers through the website • Provide postharvest materials to the farmers (Plastic crates) • Provide training on postharvest to the farmers • Through the online app, Sodai buy and sell agricultural products • To maintain agricultural marketing channel • Develop farmer's market where a farmer can directly sell their products
Supporting	**Department of Agricultural Information Service**	Government	• Provide production information towards farmers through different media like television, youtube, radio programmes, call centre (16123), leaflet magazine (Krishi Katha)

			• Provide training to use AIS for income-generating activities • Provide crop forecasting information and recommend good agricultural practices • Create awareness among farmers • Spread success story
Supporting	**Rajshahi Krishi Unnayan Bank**	Governmental Financial Institution	• Provide loans to the farmers at 8% interest • Per 1 acre (0.40 ha) land for litchi 79700 Tk (790.3 €) loan is given to the litchi farmers • The loan should be paid one year after the crop season (Crop season + one year time)
Processing	**PRAN Food Ltd.**	Private	• Process agricultural products to develop products • Buy the agricultural products from the farmers • Sell the processed products to the international and local market
Supporting	**BRAC**	NGO	• Provide training to the women • Provide land to women near their home (More or less 1 Bigha or 0.20 ha) • Provide loan with 19% interest from more than 20000 TK (198.32 €) • Collaborating with government bodies like UNO, TNO by BRAC District Coordinator (BDC) officer
Supporting	**Alor Path e Jago Jubook**	Volunteer	• Working on youth development through income-generating training • To promote litchi for the recognition of geographical indication (GI) • Increase popularity for litchi honey • Raising awareness to prevent excessive pesticide use
Producing	**Litchi producer**	Individual	• Producing litchi

			• Selling litchi to the Aratdar and Pikar per 1000 litchi 100 litchis are given extra to compensate the postharvest damage in the logistics • Selling directly to the consumer
Trading	**Aratdar**	Individual businessman	• Buying the litchi orchard at flowering stage in some cases • Selling the litchi for farmers to the Pikar from local to the national level with a service fee of 50 TK per 1000 litchi of any variety in an auction.
Wholesaling	**Pikar**	Individual businessman	• Buy litchi from the producer or Aratdar • Sell it to a national retailer • Sell it for exporting (very minute amount)
Retailing	**Retailer**	Individual business	• Selling the litchi to the local and national consumer
Consuming	**Consumer**	Individual	• Buying the litchi from a local or national retailer or directly from the producer

Source: Key informants, 2021 (Annex 4)

Department of Agricultural Information service is working on providing production-related information to the farmers through mass media. However, there is no significant work on the litchi value chain. From the interview with Rajshahi Krishi Unnayan Bank, it was stated that there is a regulation to provide loan 79700tk (790.3 €) of Per 1 acre (0.40 ha) land with 8% interest, where it was subsidised by the government to 4% during COVID-19 period. It is calculated by the government on the basis of the cost of production. With easy terms, if farmers have equal or less than 5 acres (2.02 ha) of land, they are allowed to provide with a loan without a mortgage. In reality, a mortgage is mandatory to get a loan. In the case of the litchi chain litchi, the producer sells their orchard to the trader with a contract. So, these traders are not eligible for this loan. On the other hand, BRAC provides loans mostly to women with 19% interest without a mortgage. BRAC provides works on women empowerment through training on agricultural activities and awareness. A youth organisation Alor Path e Jago Jubok working on elevating the potentiality of litchi of Dinajpur to the world through the 'Branding Dinajpur' project. They are involved in providing training on income-generating activities to the young boys in the area on honey production from litchi flowers. According to DAE, litchi honey has become popular throughout the region and gaining national demand. In this apiculture, it is reducing pesticide use in the orchards and increasing the biodiversity of the region. Moreover, this is a value addition in the litchi chain.

In the litchi value chain, litchi producers often sell their orchard after flowering for one year or for 3-4 years to the traders. In this case, traders take care of the orchard and sell it to the Pikar directly or sell it at Arat (Litchi auction market). In Arat, an auction takes place from 6 am in the morning and they charge 50 Tk (0.50 €) per 1000 litchi. The price fluctuates in the afternoon. Moreover, prices fluctuate when a good quality product arrives. From Arat, local and national pikar buy litchi. Then the Pikar sell it to the retails (Figure 7).

Figure 7 Litchi sold by the local retailer in Dinajpur

Source: Key informant no. 10, 2021

4.3 PESTEC analysis

Among the various factors affecting this litchi chain, major factors are categorised in the table below. In political factors, it is noted that there is no specific agricultural policy related to litchi, where other major crops have their policy. Agricultural policies help the stakeholders to be benefited in their activities from production to sell the products to develop the value chain. For litchi, this gap deviating the stakeholders to invest in the chain to facilitate development. Furthermore, GAP 2020 for Bangladesh is approved for introducing good agricultural practices to meet the international compliances to export. However, training and workshop on GAP are still ongoing and it is being prioritised by the government to implement in the agricultural sector. Market demand for this product is always high and consumers are willing to pay a premium price for good quality litchi. However, the application of unregulated agrochemicals preventing the consumers to trust the product. On the other hand, producers are forced to spray more or less 7 times spray to their orchards as litchi fruit borer is a major problem. Moreover, flower dropping and no flowering at all is a major factor, where farmers use agrochemicals to prevent it. Government or NGOs do not provide training and do not spread technology related to increase production and increase postharvest life. Due to these factors, agrochemicals are polluting the air, soil and water sources, which ultimately threatens the daily lives. A major social activity to promote Bedana litchi of Dinajpur as a GI product can be an important enabling factor for this chain. More factors are mentioned in detail in table 6.

Table 6 PESTEC analysis for litchi value chain

Political	Economic	Social	Technological	Environmental	Cultural
• Agricultural policy based on staple foods only • GAP 2020 is introduced • No GO and NGO help is received • No agricultural marketing consultants available • Lack of collaboration among different Govt. departments • Long time required for approval for Govt. project • Information flow through the chain is mostly one way • No litchi focused research fund and subsidies	• High market demand • High market price • Government Bank provide loans with easy terms with 8% interest and takes time • NGOs provide loans without documentation with high interest and in short time • No value addition • Price fluctuation • Pikar don't pay the money on time • Export potentiality	• Youth involvement in litchi business • On the way to be recognised as GI product	• Quality seedlings required • No early and late variety • Low and irregular production • Flower and fruit dropping • Litchi fruit borer • Bat damage the fruit • Postharvest loss • No storage facility • No postharvest technology • No cold chain • No processor involved	• Produce quality litchi in this region • High use of agrochemicals • Do not follow rules and regulation for agrochemicals • Soil, air and water pollution • High day temperature and low night temperature • Desertification of this region • Honey production improves bee population	• Women labour involved in sorting, grading and packaging • Women are not allowed to work due to social and religious region

Source: Key informants, 2021 (Annex 4)

4.4 SWOT analysis of litchi chain

Despite different factors affecting the chain of litchi, quality litchi from Dinajpur cannot match the quality of any other litchi. According to a trader, first litchi harvesting occurs at Sonargao, Dhaka and Issardi, Pabna sequentially. In the auction at Arat, Aratdar complained that there is an issue of payment on time by Pikar after the auction. Sometimes Pikar doesn't pay the price they agreed which is a problem to sell perishable crops like litchi without any postharvest management. On the other hand, for starting a new orchard, litchi producers need quality seedlings. Horticulture centre and BRAC are well known for their quality seedling, however, supply is not sufficient. Litchi producers complained that at the time of flowering they noticed that seedlings did not show the promised quality features. Furthermore, there is no postharvest management in the chain like a storage facility, proper packaging or cold chain to maintain quality. Department of Agricultural Information services stated that the production of Issardi is also competitive with Dinajpur and the use of pesticides is lesser than

Dinajpur. However, the Department of Horticulture, HSTU argued that the quality of Dinajpur litchi is superior. Moreover, high demand and high price is a major opportunity, where recent approval of GAP 2020, there will be export potential for this litchi, where current export is not significant enough and import of litchi has been recorded by the plant quarantine wing, DAE (Annex 5). Although current production is not significant enough to meet the current demand. DAE stated that in 2021, this year target production was 45000 Metric tonnes and 2000 core TK production, although it was not met. This year price of litchi was higher than the previous year due to right selling time during the Eid festival, where people were highly interested to buy litchi. Detailed Strengths, weaknesses, opportunities and threats are presented in table 7.

Table 7 SWOT analysis of litchi value chain

Strength	Weakness
• High quality standard of produced litchi in Dinajpur	• Pikar don't pay the money on time • Quality seedlings required • No early and late variety • Low and irregular production • Flower and fruit dropping • Litchi fruit borer • Bat damage the fruit • Postharvest loss • No storage facility • No postharvest technology • No cold chain • No processor involved • High use of agrochemicals • Do not follow rules and regulation for agrochemicals
Opportunities	**Threats**
• High market demand • High market price • Litchi honey production • GAP 2020 is introduced • Government Bank provide loans with easy terms with 8% interest • Export potentiality • On the way to be recognised as GI product • Youth involvement in litchi business	• Agricultural policy based on staple foods only • No GO and NGO help is received • No agricultural marketing consultants available • Lack of collaboration among different GO departments • Long time required for approval for Govt. project • Information flow through the chain is mostly one way • No litchi focused research fund and subsidies • NGOs provide loans without documentation with high interest • Desertification of this region • High day temperature and low night temperature

Source: Author, 2021

4.5 Gender role

In the litchi chain, according to the statement from the key informants all the land ownership and the major activities are conducted by men. However, in some cases, women participate in fertiliser

application and harvesting. Women mainly participate in litchi sorting, grading and packaging (Figure 8). All the other access and control is highly filled with men. However, the involvement of women in doing sorting and grading in litchi orchards is the key scenario. Harvard analytical tool is used to present the gender activities, access and control in table 8.

Figure 8 Litchi sorting and grading by women in a litchi orchard

Source: Key informant no. 10, 2021

Table 8 Harvard analytical tool for gender activity, access and control analysis

Production activities	Women	Men
Raising seedling		√
Planting seedling		√
Land preparation		√
Fertiliser application	√	√
Irrigation		√
Pesticide application		√
Training or pruning of branches		√
Preharvest practices		√
Harvesting	√	√
Postharvest practices	√	√

Resource	Access		Control	
	Women	Men	Women	Men
Land		√		√
Seedling		√		√
Fertiliser		√		√
Irrigation water		√		√
Pesticides		√		√
Finance		√		√
Labour		√		√
Equipment		√		√
Extension services		√		√
Benefits				
Profit		√		√
Power		√		√
Collaboration		√		√
Reinvestment		√		√

Source: Key informants, 2021 (Annex 4)

4.6 Value share

From the interview data, it was noted that the price of litchi varies due to size, colour, age of trees, time of auction and practices in the litchi orchard. The price of litchi fluctuates in the chain unpredictably. For example, Bedana variety litchi was sold in 2021 from 6000 to 12000 Tk (59.5 – 118.99 €) per 1000 litchi. In litchi production, the whole orchard with different varieties is leased with contract depending on age, flowering and quality of litchi. Overall, the price of a tree ranges from 1764.71 – 2500 Tk (17.46 - 24.79 €). Moreover, investment in litchi orchards is not constant as producers do not produce litchi as the main crop. Orchard management varies on their financial situation. The total variable cost overview is presented in the pie chart for Bombai litchi (Figure 9). However, here a general overview of cost per 1000 litchi is presented in table X, where depreciation costs and fixed costs were not calculated. In table 9 it can be observed that Bedana has the highest B: C value 6.49 where Madraji has the lowest value 1.90. As the unit price for Bedana is higher than other varieties, B: C is also higher. Moreover, popular variety like Bombai has B: C of 2.49 and China 2 is 4.33. The unit price of China 2 variety is not higher than Bedana, however, the production is higher, which resulted in more profit.

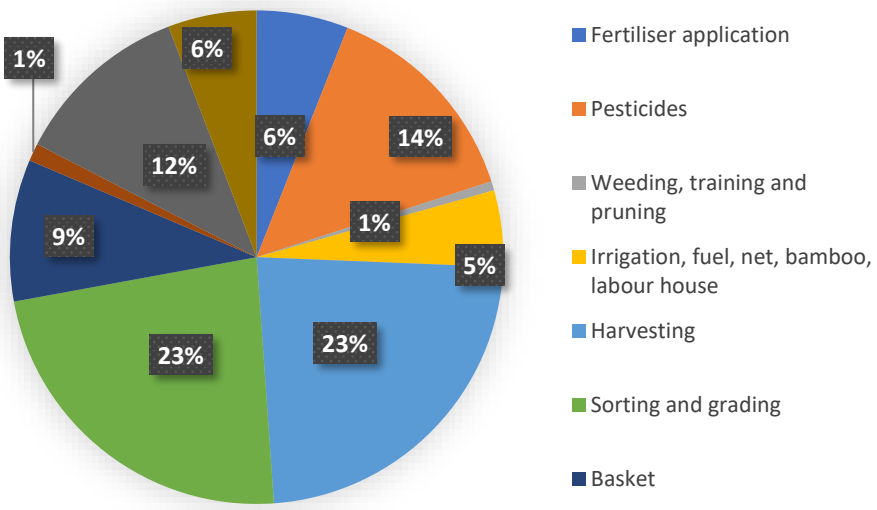


Figure 9 Distribution of total variable cost for litchi in percentage

Source: Key informants, 2021 (Annex 4)

Table 9 Total variable cost and B: C for different varieties of litchi

Item	Bombai (per 1000 litchi) Tk	Bedana (per 1000 litchi) Tk	Madraji (per 1000 litchi) Tk	China 2 (per 1000 litchi) Tk
Cow dung	27.59 (0.27 €)	36.78 (0.37 €)	27.59 (0.27 €)	13.79 (0.14 €)
DAP	10.34 (0.1 €)	13.79 (0.14 €)	10.34 (0.1 €)	5.17 (0.05 €)
MOP	6.90 (0.07 €)	9.20 (0.09 €)	6.90 (0.07 €)	3.45 (0.03)
Labour for fertiliser	6.90 (0.07 €)	9.20 (0.09 €)	6.90 (0.07 €)	3.45 (0.03 €)
Pesticide	120.69 (1.2 €)	160.92 (1.6 €)	120.69 (1.2 €)	60.34 (0.6 €)
Weeding, training, pruning	5.17 (0.05 €)	6.90 (0.07 €)	5.17 (0.05 €)	2.59 (0.03 €)
Irrigation, labour house, fuel, net, bamboo	43.10 (0.43 €)	57.47 (0.57 €)	43.10 (0.43 €)	21.55 (0.21 €)
Harvesting	200.00 (1.98 €)	200.00 (1.98 €)	200.00 (1.98 €)	200.00 (1.98 €)
Sorting grading	200.00 (1.98 €)	200.00 (1.98 €)	200.00 (1.98 €)	200.00 (1.98 €)
basket	80.00 (0.79 €)	80.00 (0.79 €)	80.00 (0.79 €)	80.00 (0.79 €)
packaging	10.00 (0.1 €)	10.00 (0.1 €)	10.00 (0.1 €)	10.00 (0.1 €)
Transport	100.00 (0.99 €)	100.00 (0.99 €)	100.00 (0.99 €)	100.00 (0.99 €)
Aratdar payment	50.00 (0.5 €)	50.00 (0.5 €)	50.00 (0.5 €)	50.00 (0.5 €)
Total variable cost	860.69 (8.53 €)	934.25 (9.26 €)	860.69 (8.53 €)	750.34 (7.44 €)
Selling price	3000.00 (29.75 €)	7000.00 (69.41 €)	2500.00 (24.79 €)	4000.00 (39.76 €)
Profit	2139.31 (21.21 €)	6065.75 (60.15 €)	1639.31 (16.26 €)	3249.66 (32.22 €)
B:C	2.49	6.49	1.90	4.33

Source: Key informants, 2021 (Annex 4)

In the following table no. 10, value share calculation is presented. It is noted that estimation of cost of Pikar and Retail varies region to region. However, for an overview, the variable cost is estimated for these actors according to the findings of this research. Moreover, this value share calculation is shown for Bombai litchi variety when a contract farm takes the orchard on contract for one year. In the case of other litchi varieties, it will vary according to quality, colour and market demand and supply.

Table 10 Value share for Bombai litchi

Actors	Total variable cost (Tk)	Revenue (Tk)	Gross income (Tk)	Gross margin (%)	Value share (%)
Litchi producer	**1301.87 (12.91 €)**	**3000 (29.75 €)**	**1698.13 (16.84 €)**	**56.60**	**90.90%**
Pikar	**3100 (30.74 €)**	**3150 (31.24 €)**	**50 (0.5 €)**	**1.59**	**4.55%**
Retail	**3200 (31.73 €)**	**3300 (32.72 €)**	**100 (0.99 €)**	**3.03**	**4.55%**

Source: Author, 2021

4.7 Litchi producers in Dinajpur

From this study, fifty litchi farmers from different farm sizes were involved in data collection (Figure 13). Among them, 44% are contact farmers and 56% own their own farm. Furthermore, in terms of farm size, there is a significant difference in the case of the number of trees in their orchard (Annex 6 and 8), where P = 0.00. Farm group A (Less than 0.50 ha), Farm group B (0.50 - 0.75 ha) and Farm group C (More than 0.75 ha) contains mean a number of trees 28.64, 62.67 and 219.4 respectively (Figure 10). Moreover, there is a significant difference in the number of varieties selected in different farm groups where P =0.00.

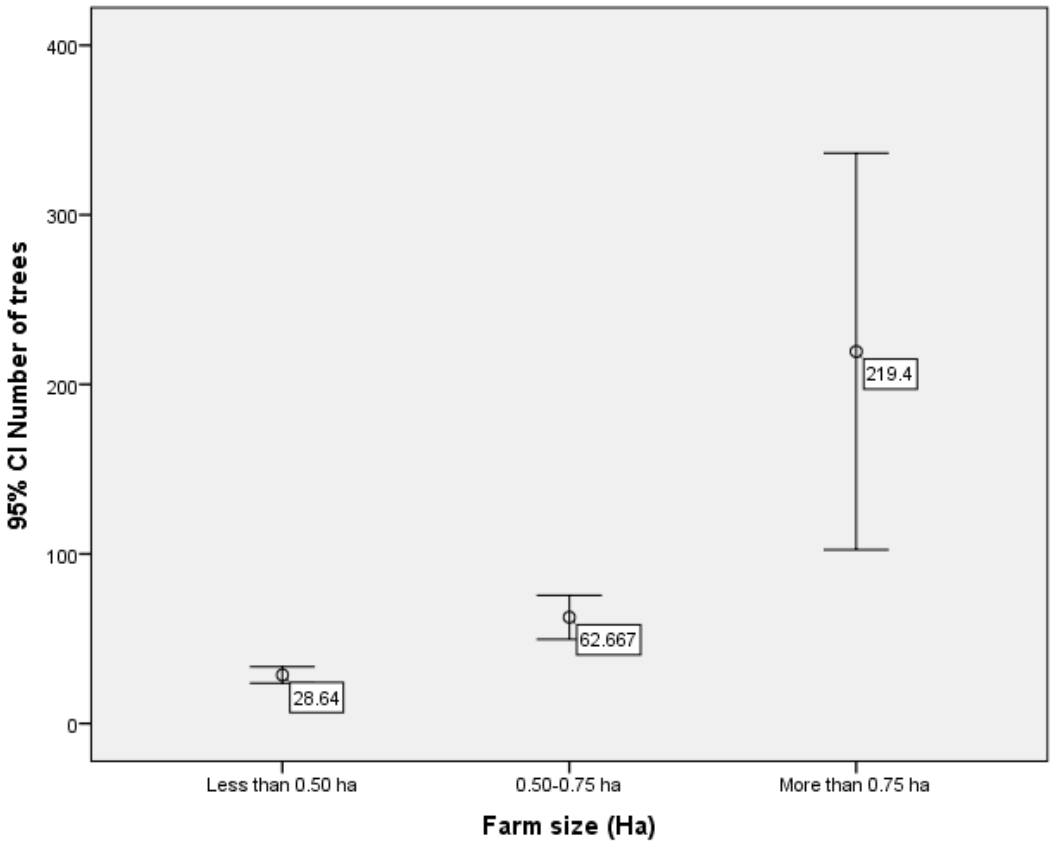


Figure 10 Number of trees present in an orchard according to different farm sizes

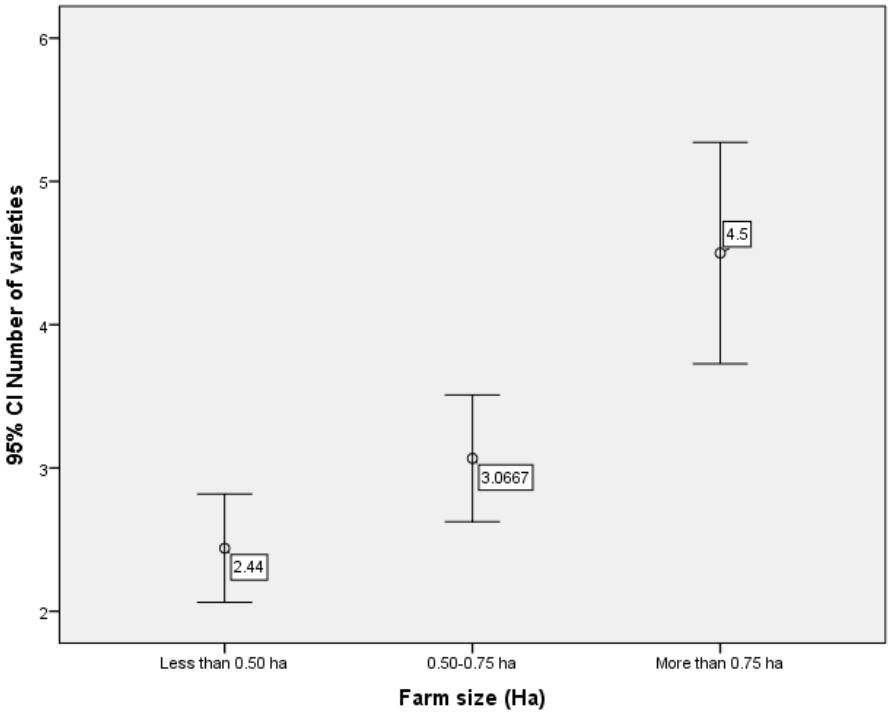


Figure 11 Number of varieties present in an orchard according to different farm sizes

From figure 12, it can be noted that 36 out of 50 litchi producers use Bombai variety, where 31 and 27 producers use Madraji and Bedana variety respectively. China 1 is the least selected variety, where Kathali is mentioned by the 7 producers (Figure 12).

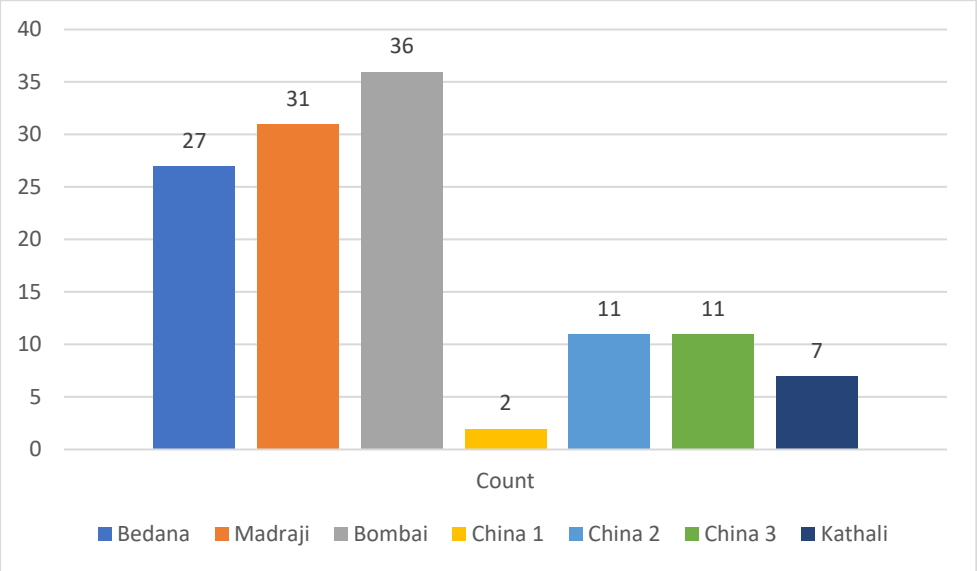


Figure 12 Different variety selection by litchi producers

Figure 13 Litchi orchard

Source: Author, 2021

4.8 Preharvest technology in litchi production

Different preharvest technology training and practice with their frequent use is described in this section.

4.8.1 Training on preharvest technology

According to interview data, there is no training provided on preharvest technology provided on litchi. From the study ten respondents received training from NGOs, DAE, Horticulture Centre on preharvest technology on other fruits, however, this training is not directly related to litchi preharvest management. It is concluded from this response that respondents are using their previous training experience in litchi cultivation. Respondents stated that they rely on their own experiences for years and recommendations from the agricultural input suppliers for their activities. All the respondents stated that they were satisfied with the training they received (Table 11).

Table 11 Training received on preharvest technology by the litchi producers

Training location	Farm size			Satisfaction level		Farm size	
	Less than 0.50 ha	0.50-0.75 ha	More than 0.75 ha		Less than 0.50 ha	0.50-0.75 ha	More than 0.75 ha
Horticulture centre	-	2	-	Satisfied	3	6	1
NGOs	3	2	-				
Others	-	-	1				
DAE & NGOs	-	2	-				
Total	3	6	1	Total	3	6	1

4.8.2 Preharvest technology practice

Preharvest practice is applied by all the respondents in the study. Calcium and Boron spray, plant growth regulators and pesticides are common preharvest technology among 45, 47 and 50 respondents respectively (Figure 14). There are no significant differences in the selection of preharvest technology among different farm sizes. Moreover, electric bulbs, metal sheets are also used in the time of fruiting. These are used for scaring away the bats. In terms of choosing these preharvest technology, easy access (38) and price (31) of the technology and concern about more production is the main driver (Figure 15). On the other hand, pesticides are ranked 5 out of 5 and used very frequently as it is necessary to prevent litchi fruit borer by any means (Table 12).

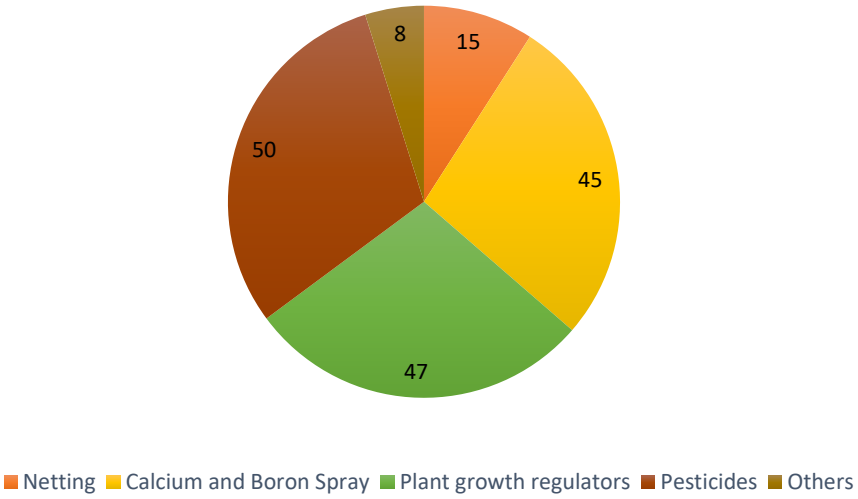


Figure 14 Different preharvest technology used by the litchi producers

Table 12 Preharvest technology use and ranking by the litchi producers

Preharvest technology	Preharvest technology rank		Preharvest technology use	
	Frequency	Median	Frequency	Median
Fruit bagging	-	-	-	-
Netting	15	3	15	3
Calcium and Boron Spray	45	3	45	3
Plant growth regulators	47	3	47	3
Pesticides	50	5	50	5
Others (Bulbs/ tins)	8	4	8	5

Preharvest technology scale 1-5; Preharvest technology use: 1: Very infrequently, 2: Somewhat infrequently, 3: Occasionally, 4: Somewhat frequently, 5: Very frequently

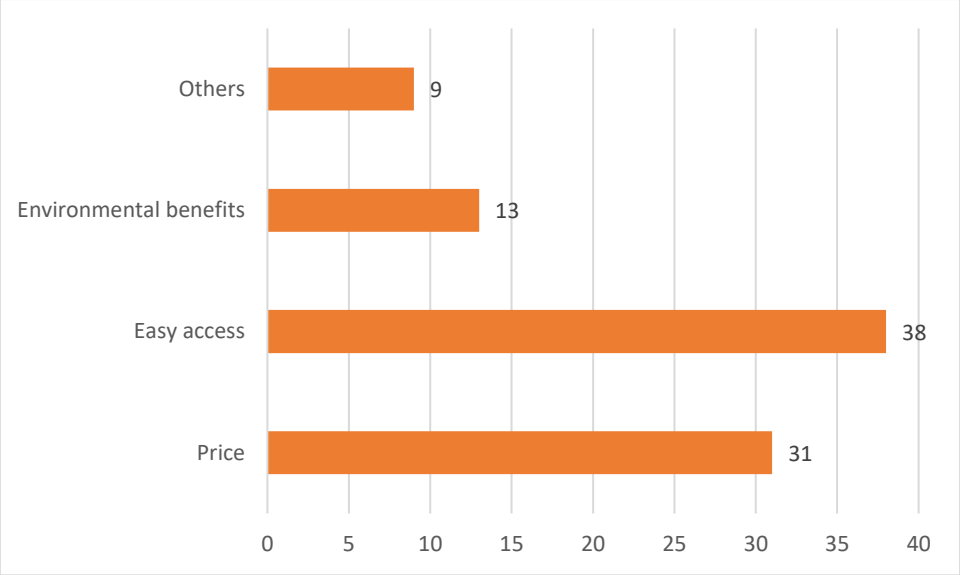


Figure 15 Reason for choosing preharvest technology

4.9 Postharvest technology in litchi production

Postharvest technology training and practice are described in this section.

4.9.1 Training on postharvest technology

Training on postharvest technology is provided by the DAE, however, there is no training on litchi. In this study, 5 respondents stated that they took training from Horticulture centre, DAE and NGOs (Table 13). It is noted that these trainings are focused on general postharvest management. Moreover, respondents were satisfied with their training. In figure 16 it is observed that 35 respondents use postharvest technology in their practice. Although there is no significant difference in their response among different farm sizes.

Table 13 Training received on postharvest technology by the litchi producers

Training location	Farm size			Satisfaction level	Farm size		
	Less than 0.50 ha	0.50-0.75 ha	More than 0.75 ha		Less than 0.50 ha	0.50-0.75 ha	More than 0.75 ha
Horticulture centre	-	2	-	Satisfied	-	4	1
DAE	-	-	1				
Horticulture centre, DAE & NGOs	-	2	-				
Total	-	4	1	Total	-	4	1

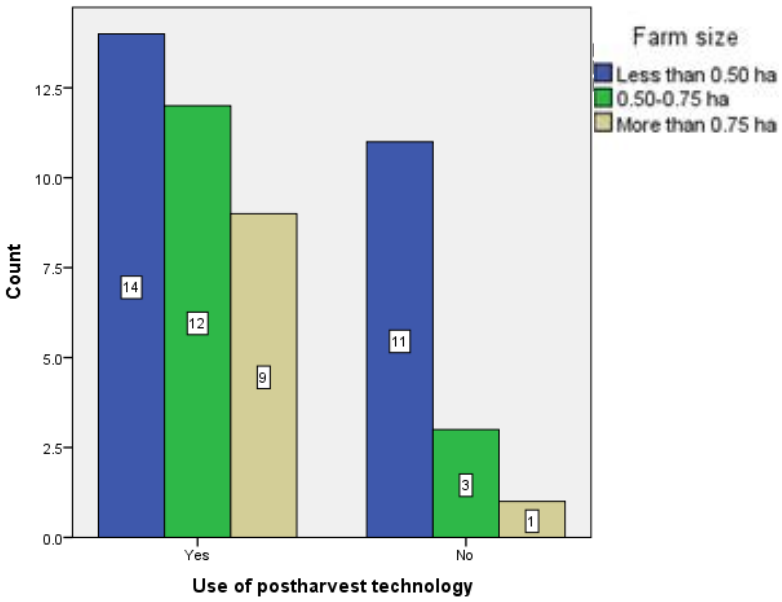


Figure 16 Postharvest technology use according to different farm sizes

4.9.2 Harvesting methods

Litchi is harvested from the tree using direct hand picking, climbing the tree and using ladder by 50, 43 and 27 litchi producers respectively (Figure 17). In another method bamboo pole named Aksi is used by 4 producers to harvest litchi. As litchi is a small fruit, using the ladder (Figure 18) to harvest litchi is ranked 5 out of 5 and used very frequently with the climbing tree method by the respondents (Table 14). However, there is no significant difference in selecting the harvesting method among different farm sizes.

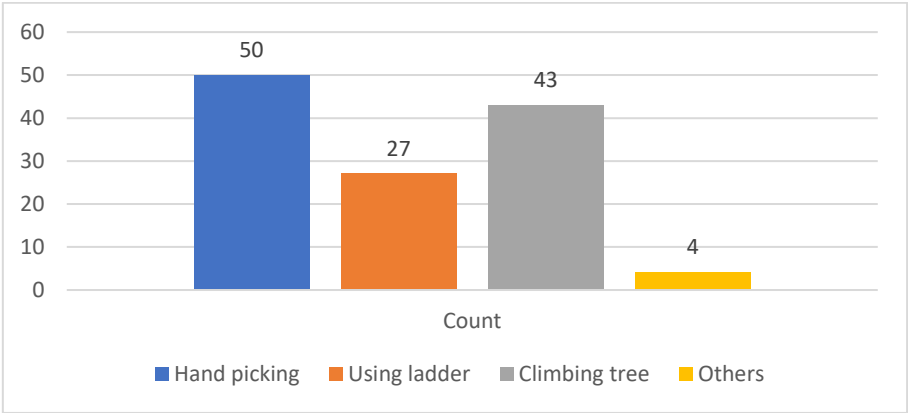


Figure 17 Different harvesting methods used by the litchi producers

Table 14 Ranking and use of different harvesting methods by the litchi producers

Harvesting method	Harvesting method ranking		Harvesting method use	
	Frequency	Median	Frequency	Median
Hand picking	50	3	50	3
Using ladder	27	5	27	5
Climbing tree	43	4	43	5
Using machineries	-	-	-	-
Others	4	3.50	4	4

Harvesting method ranking scale 1-5; Harvesting method use: 1: Very infrequently, 2: Somewhat infrequently, 3: Occasionally, 4: Somewhat frequently, 5: Very frequently

Figure 18 Harvesting of litchi using a ladder

Source: Author, 2021

4.9.3 Packaging method

For packaging bamboo basket (48) and plastic crate (40) is the most common method among the litchi producers (Figure 19, 21 and 22). In past, only bamboo baskets were used in packaging. Now due to the awareness of using better packaging for reducing postharvest loss among the traders by DAE and DAM, plastic crates are used for packaging. Government organisations like DAM and DAE are influencing the producers to use the plastic crate for transportation to minimize the postharvest loss.

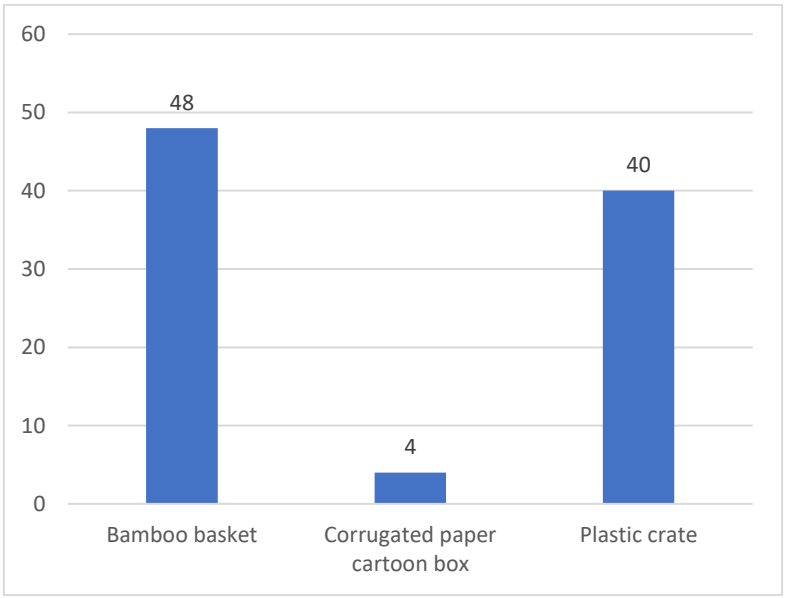


Figure 19 Different packaging methods used by the litchi producers

Price and easy access to these packaging materials are considered important reasons for choosing this method (Figure20). Moreover, respondents ranked plastic crates 5 out of 5 and they use the plastic crate, bamboo basket very frequently (Table 15). However, a small number of respondents said they use corrugated paper boxes very frequently. Furthermore, there is a significant difference in using the bamboo basket and plastic crate among different farm sizes (Annex 7, 9 and 10).

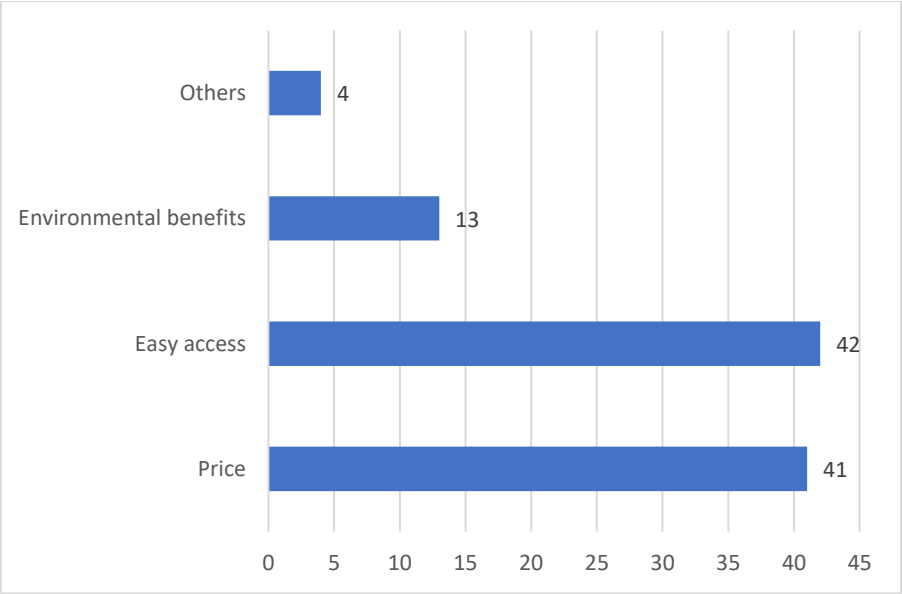


Figure 20 Reason for selecting different packaging method

Table 15 Ranking and use frequency of different packaging methods

Packaging	Packaging rank		Packaging use	
	Frequency	Median	Frequency	Median
Bamboo basket	48	4	48 (A = 24, B = 14, C = 10	5*
Corrugated paper cartoon box	4	4	4 (A = 3, C = 1)	5
Plastic crate	40	5	40 (A = 17, B = 13, C = 10)	5*
Modified atmosphere packaging	-	-	-	-
LDPE	-	-	-	-
Others	-	-	-	-

Packaging ranking scale 1-5; Packaging use: 1: Very infrequently, 2: Somewhat infrequently, 3: Occasionally, 4: Somewhat frequently, 5: Very frequently; Farm group A = Less than 0.50 ha, Farm group B = 0.50 - 0.75 ha) and Farm group C = More than 0.75 ha; *significant difference found among different litchi farm size ($P \leq 0.05$)

Figure 21 Bamboo basket packaging

Source: Author, 2021

Figure 22 Plastic crate packaging

Source: Author, 2021

4.9.4 Filling material use

In figure23 it is presented that leaf (59%) and paper (41%) is the most common filling material used by the litchi farmers (Figure 24 and 25). A reasonable price and easy access are the main factors for selecting this filling material. On the other hand, the leaf is ranked 5 out of 5 and very frequently used by different farm size litchi producers (Table 16). Moreover, there is a significant difference in ranking and use of leaf material among different farm sizes (Annex 7, 11 and 12).

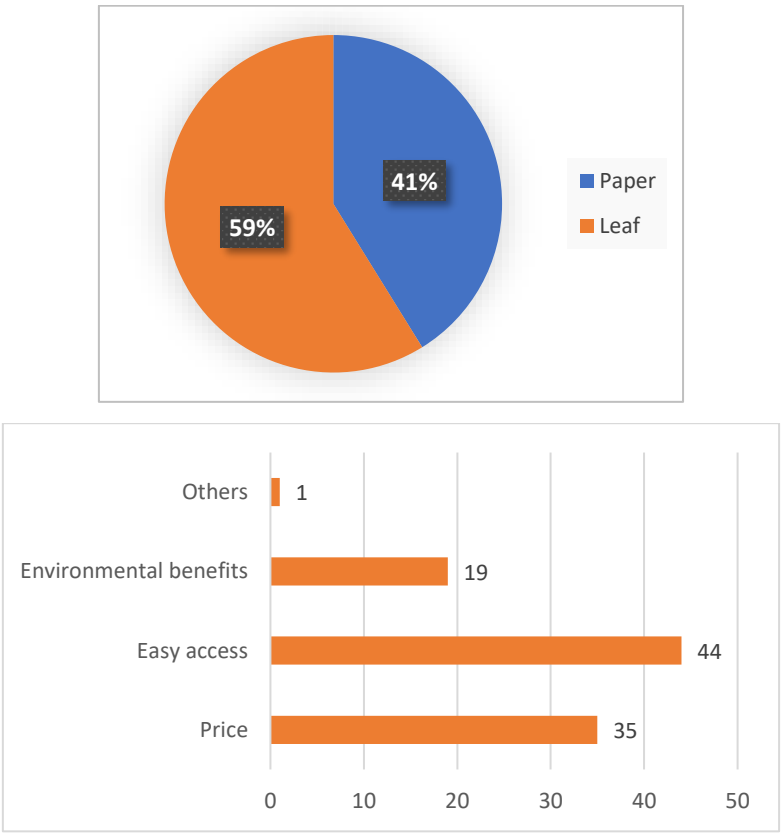


Figure 23 Filling material selection by the litchi producers (pie chart) and reason for selecting filling material

Figure 24 Litchi leaves used as filling material in a bamboo basket

Source: Author, 2021

Figure 25 Paper and litchi leaves used as filling material in a plastic crate packaging

Source: Author, 2021

Table 16 Filling material use and ranking by the litchi producers

Filling material	Filling material ranking		Filling material use	
	Frequency	Median	Frequency	Median
Paper	35	3	35	3
Leaf	50	5*	50	5*
Polythene	-	-	-	-
None	-	-	-	-
Others	-	-	-	-

Filling material ranking scale 1-5; Filling material use: 1: Very infrequently, 2: Somewhat infrequently, 3: Occasionally, 4: Somewhat frequently, 5: Very frequently; *significant difference found among different litchi farm sizes ($P \leq 0.05$)

4.9.5 Use of transportation

Auto van is a battery operated electric small vehicle available all over Dinajpur is used very frequently by the litchi producers which is selected by 45 producers out of 50 (Figure 26 and 29). Price and easy access to this transportation is the main reason to use this vehicle to carry it to the nearest Arat for auction (Figure 27). For long destination truck and pick up trucks are used (Figure 30 and 31). In table 17 auto van is ranked 5 out of 5 by the respondents and there is a significant difference in ranking and using the auto van among different farm sizes (Annex 7, 13 and 14). Bus and tricycle van usage is also common in this chain, however, it was not reported by the litchi producers (Figure 28 and 32).

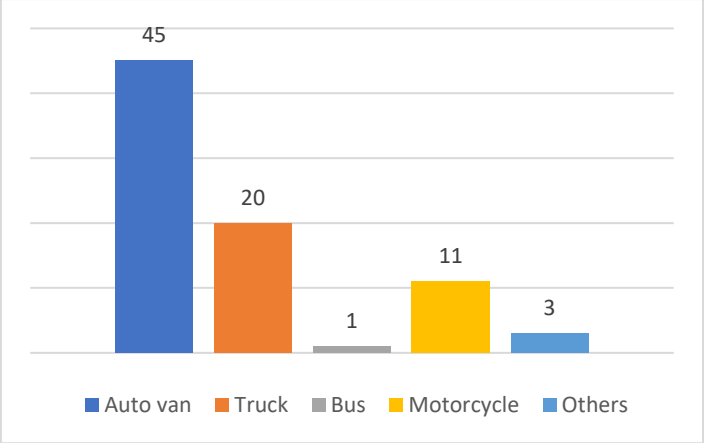


Figure 26 Selection of different transportation by the litchi producers

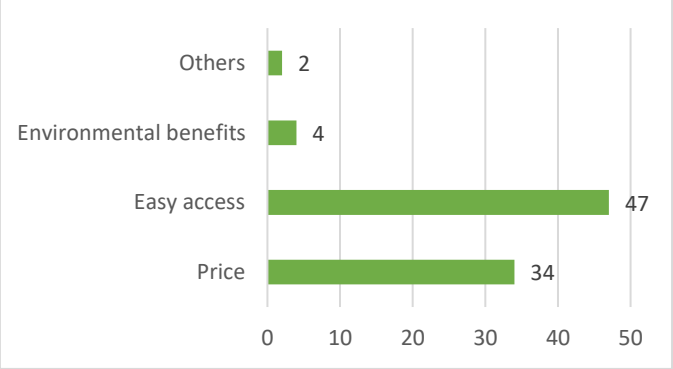


Figure 27 Reason for choosing different transportation

Table 17 Transportation method ranking and use

Transportation	Transportation rank		Transportation use	
	Frequency	Median	Frequency	Median
Auto van	45 (A = 22, B = 14, C = 9)	5*	45 (A = 22, B = 14, C = 9)	5*
Tricycle van	-	-	0	-
Truck	20	5	20	3.5
Bus	1	1	1	2
Motorcycle	11	4	11	4
Temperature and moisture-controlled vehicle	-	-	-	-
Others	3	5	3	5

Transportation ranking scale 1-5; Transportation use: 1: Very infrequently, 2: Somewhat infrequently, 3: Occasionally, 4: Somewhat frequently, 5: Very frequently; Farm group A = Less than 0.50 ha, Farm group B = 0.50 - 0.75 ha) and Farm group C = More than 0.75 ha; *significant difference found among different litchi farm sizes ($P \leq 0.05$)

Figure 28 Using tricycle van for transporting for litchi
Source: Author, 2021

Figure 29 Using auto van for transportation for litchi

Source: Author, 2021

Figure 30 Using pick up truck for transportation for litchi

Source: Author, 2021

Figure 31 Using truck as transportation

Source: Author, 2021

Figure 32 Using bus as transportation for litchi

Source: Author, 2021

4.10 Postharvest loss in terms of money and fruit number

In figure 33 it is presented that farm group A loses 138.8 (13.88%), farm group B loses 152.67 (15.27%) and farm group C loses 192 (19.20%) litchi per 1000 litchi respectively.

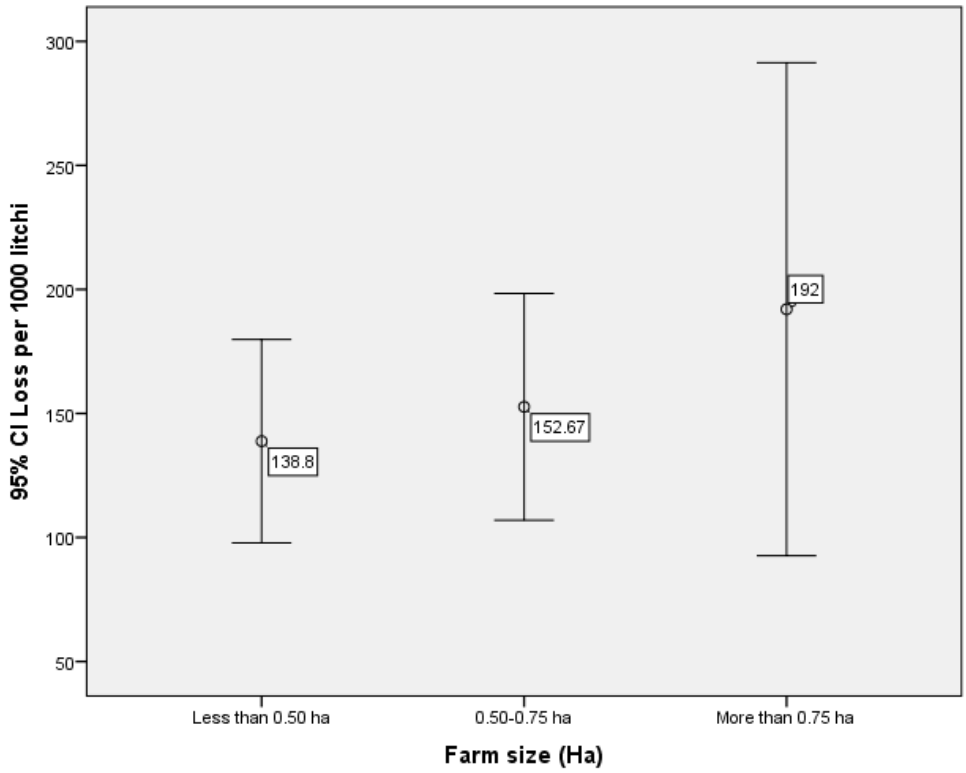


Figure 33 Loss per 1000 litchi in different farm sizes

Moreover, farm group A loses 299.8 Tk (29.98%), farm group B 346 Tk (34.60%) and farm group C 320 Tk (32.00%) per 1000 Tk in postharvest loss (Figure 34). However, there is no significant difference in the postharvest loss in 1000 litchi and 1000 Tk among different farm sizes.

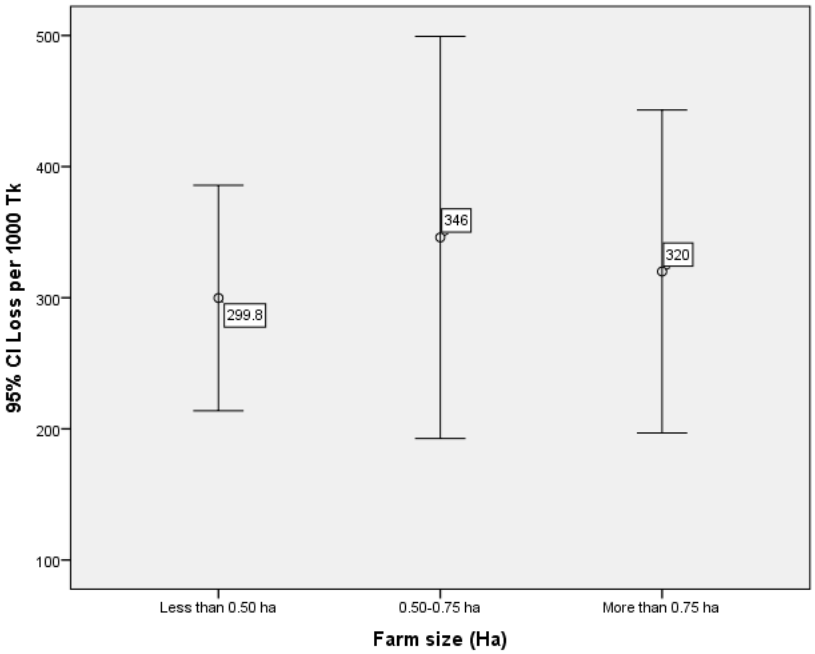


Figure 34 Loss per 1000 Tk in different farm sizes

4.11 Money spend on pre and postharvest technology

Larger size farm invests more money in pre and postharvest technology than the smaller farm. From the figure, it is presented that farm group A spend 26320 Tk, farm group B spend 48267 Tk and farm group C spend 137000 Tk on preharvest technology (Figure 35), where farm group A spend 12820 Tk, farm group B spend 22600 Tk and farm group C spends 60120 Tk for postharvest technology (Figure 36).

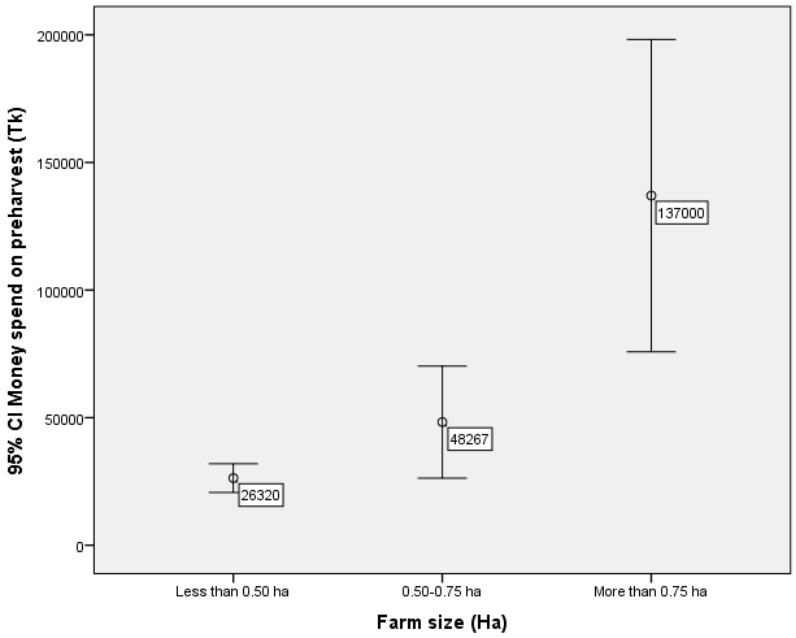


Figure 35 Money spend on preharvest technology according to different farm sizes

Moreover, there is a significant difference in money spend on pre (P = 0.00) and postharvest (P = 0.00) technology among different farm sizes (Annex 6 and 8). Satisfaction of spending money is ranked 4 out of 5.

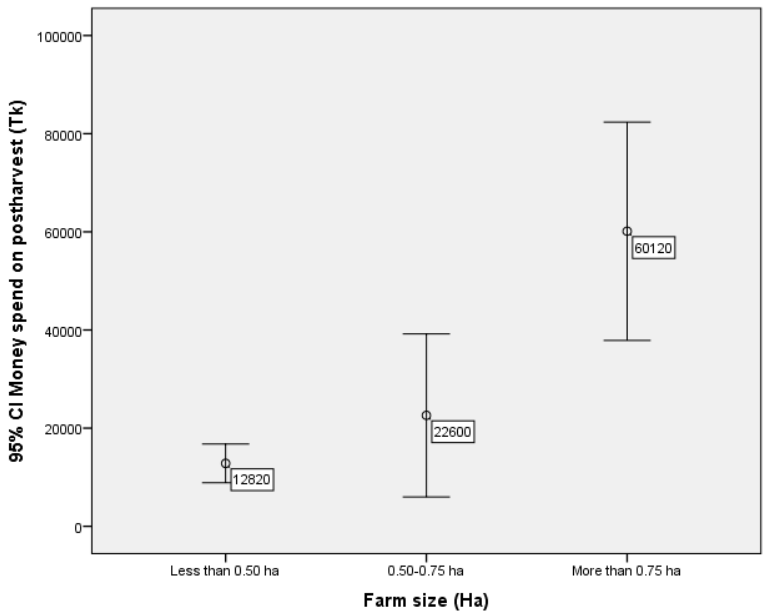


Figure 36 Money spend on postharvest technology according to different farm sizes

4.12 Availability of finance and reinvestment in the economic assessment

In this study, a positive response from 40 respondents was recorded for the availability of finance for pre and postharvest practices (Figure 37: A). On the other hand, 38 respondents stated that they have the capability to reinvest in litchi business (Figure 37: B). However, there are no significant differences in availability of finance for pre and postharvest and reinvestment among different farm sizes.

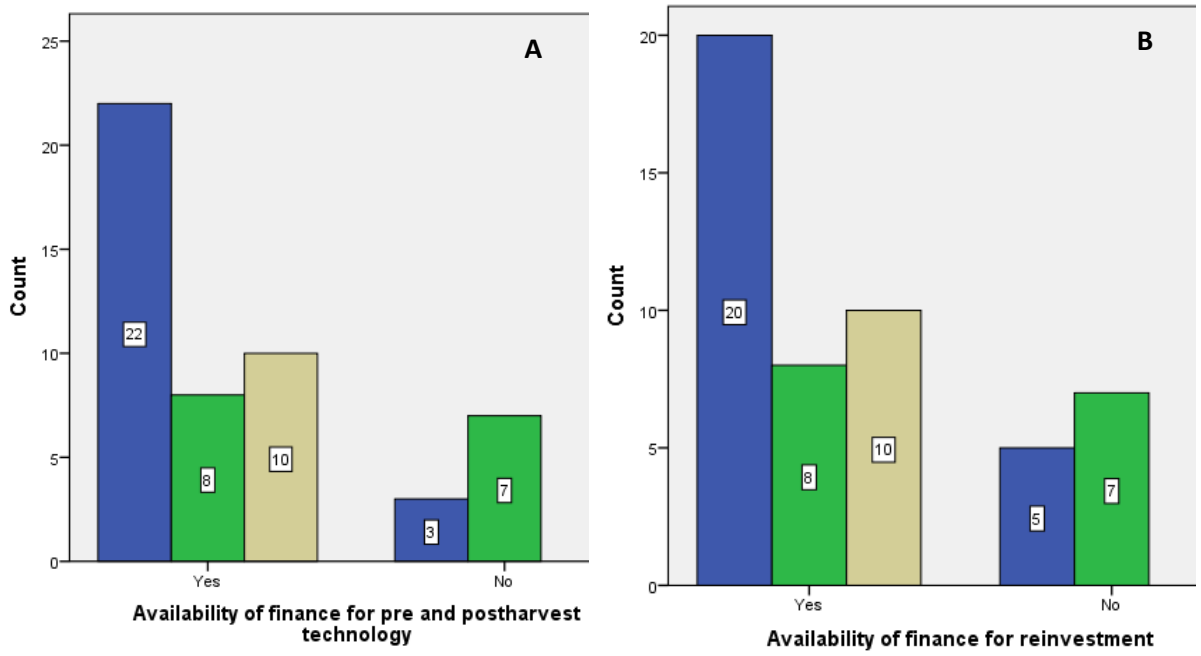


Figure 37 A: availability of finance for pre and postharvest technology among different farm sizes; B: availability of finance for reinvestment

4.13 Environmental assessment

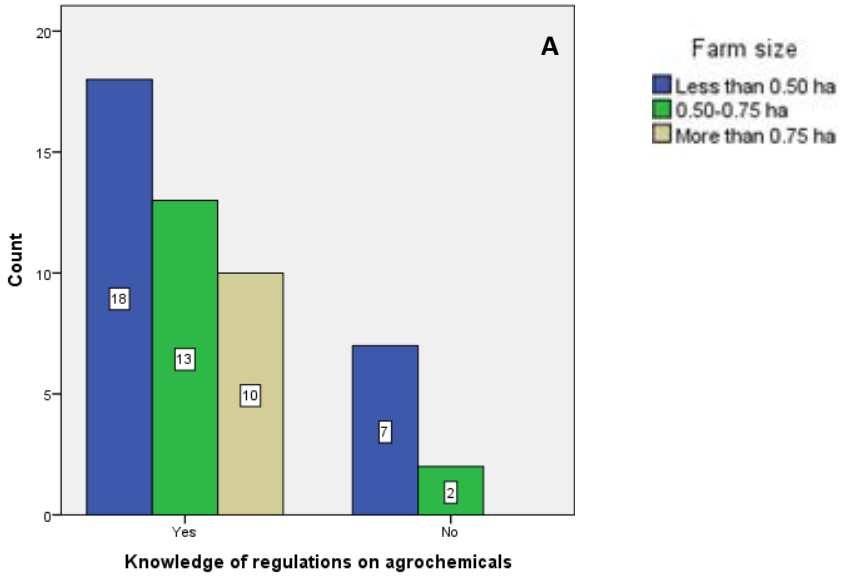
4.13.1 Waste management

The practice of waste management methods is presented in figure 38: A, where 34 respondents stated they do practise waste management. However, burning of the waste is the most common waste management among the respondents by 24 producers (Figure 38: B). In other methods, it was noted that leaves and branches are sold for fuel or allowed to decompose in the orchard or allowed others to collect for fuel purposes.

Figure 38 A: practice of waste management among different farm sizes; B: waste management methods

4.13.2 Knowledge of agrochemicals and awareness of biodiversity and environment-friendly packaging

Among the litchi producers 41, 32 and 38 respectively responded positively to the knowledge of the rules and regulations of agrochemicals, awareness of biodiversity and environment-friendly packaging (Figure 39).



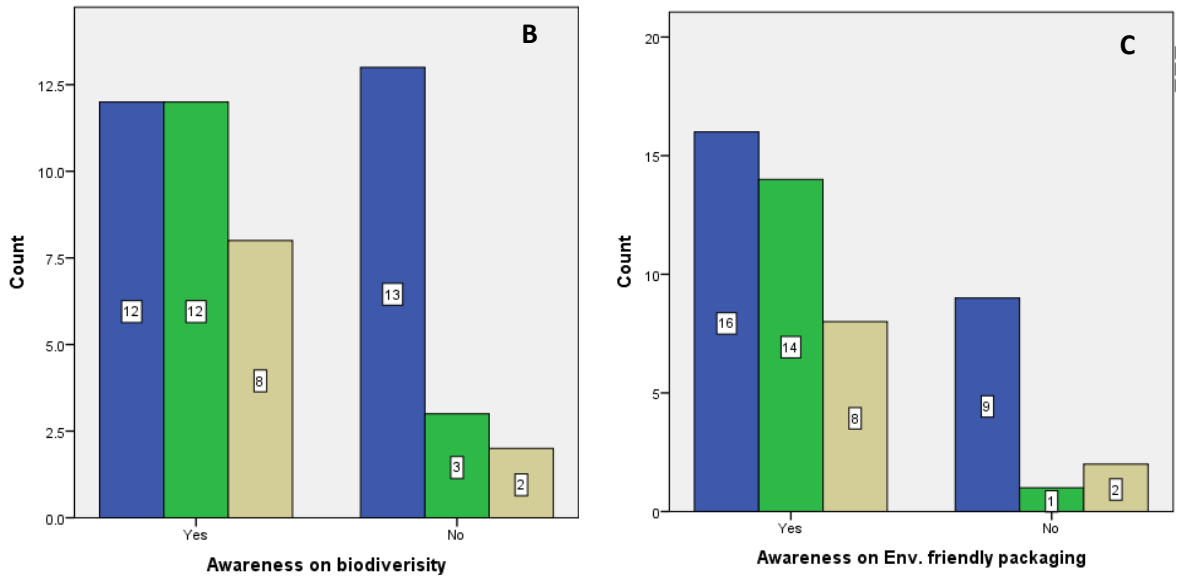


Figure 39 A: knowledge of agrochemicals among different farm sizes; B: awareness of biodiversity among different farm sizes; C: awareness of environment-friendly packaging among different farm sizes

However, they ranked 5 out of 10 for knowledge of regulation on agrochemicals, 4 out of 10 for awareness for biodiversity and 4.5 out of 10 for awareness on environment-friendly packaging. Moreover, there is no significant difference in these variables among different farm sizes (Table 18).

Table 18 Ranking of knowledge of agrochemicals, awareness of biodiversity and environment-friendly packaging

Agrochemical rules knowledge rank		Biodiversity knowledge rank		Environment-friendly packaging rank	
Frequency	**Median**	**Frequency**	**Median**	**Frequency**	**Median**
45	5 out of 10	32	4 out of 10	38	4.50 out of 10

Satisfaction on cost ranking scale 1-5; Agrochemical rules knowledge, Biodiversity knowledge & Environment-friendly packaging ranking scale: 1-10

4.14 Correlation among different variables in litchi production and postharvest loss

Data from the questionnaire is analysed for finding correlations among different variables. Two variables with significant correlation are presented here for discussion. The results of the correlation analysis are presented in Annex 15. In figure 40, it is presented that there is a moderate positive correlation between the number of trees and the number of varieties with a correlation coefficient value of 0.441. On the other hand, the number of trees and money spend on preharvest has a moderate positive correlation with a value of 0.634 (Figure 41). In figure 42, the number of trees and money spend on postharvest shows a moderate positive correlation (0.359). This illustrates that the increasing number of trees causes an increase in money spent on pre and postharvest practices. Moreover, in figure 43, an increasing number of varieties cause an increase in money spent on preharvest with a moderate positive correlation (0.498).

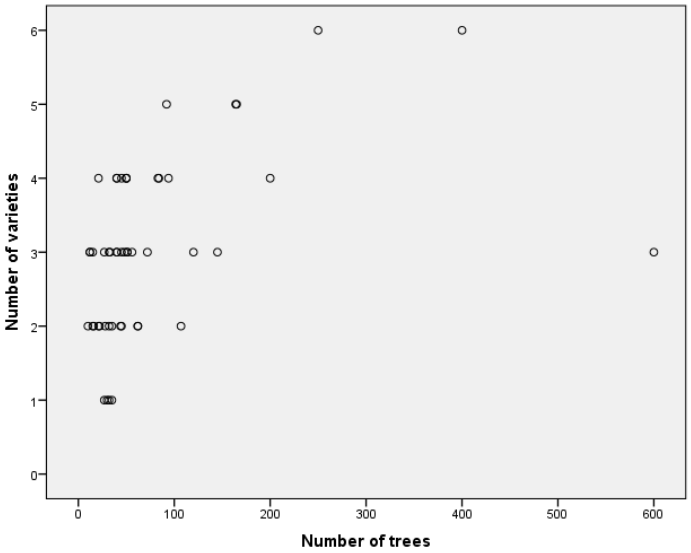


Figure 40 Correlation between number of trees and number of varieties (Correlation coefficient value: 0.441)

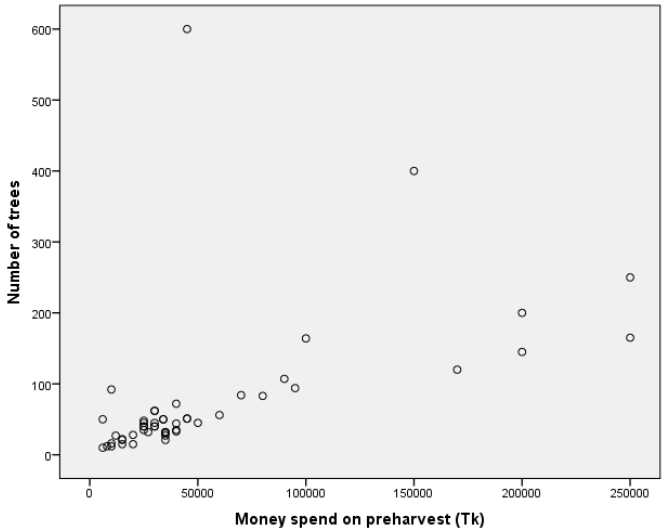


Figure 41 Correlation between money spend on preharvest (Tk) and number of trees (Correlation coefficient value: 0.634)

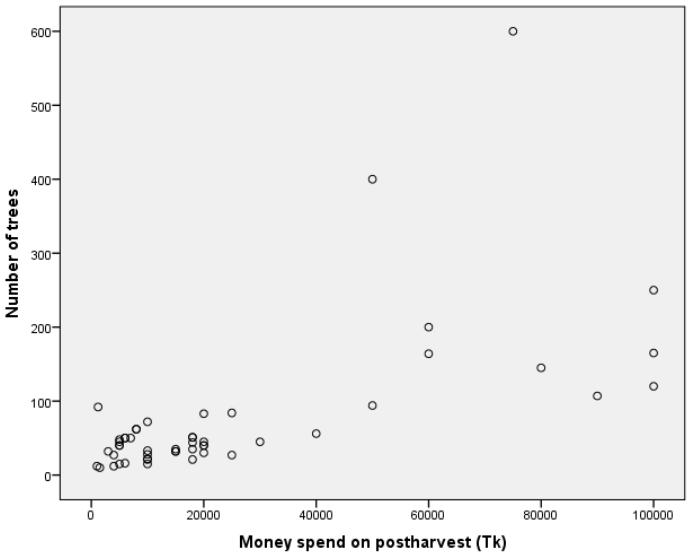


Figure 42 Correlation between money spend on postharvest (Tk) and number of trees (Correlation coefficient value: 0.359)

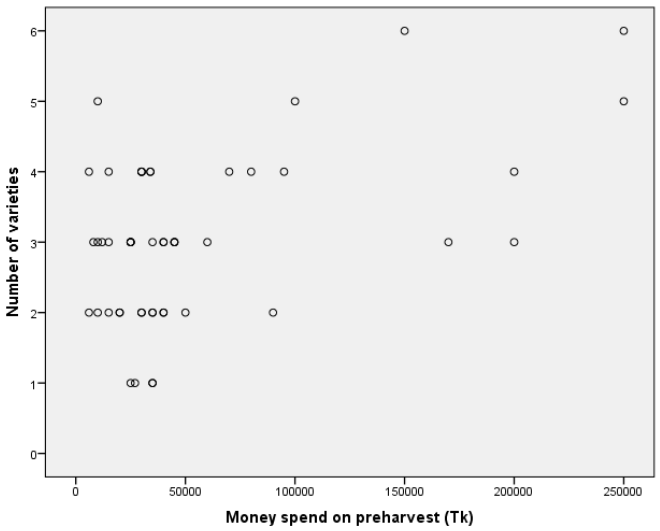


Figure 43 Correlation between money spend on preharvest (Tk) and number of varieties (Correlation coefficient value: 0.498)

In the following figure 44, it is observed that loss per 1000 litchi is causing an increase in loss per 1000 Tk with a moderate positive correlation value of 0.673. Money spends on preharvest increases as the money spends on postharvest increases with a strong positive correlation value of 0.878 (figure 45). As the farm size and number of trees increase money to spend on pre and postharvest increases and create a strong correlation. On the other hand, when the Calcium and Born spray and plant growth regulators increase when the loss per 1000 litchi decreases with a moderate negative correlation value of -0.620 and-0.514 respectively (Figure 46 and 47).

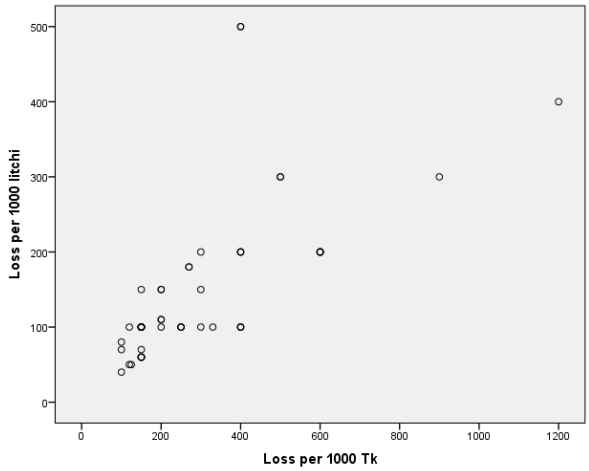


Figure 44 Correlation between loss per 1000 Tk and loss per 1000 litchi (Correlation coefficient value: 0.673)

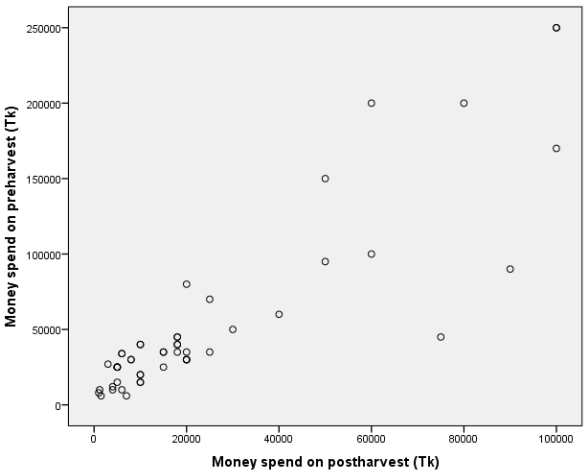


Figure 45 Correlation between money spend on postharvest (Tk) and money spend on preharvest (Tk) (Correlation coefficient value: 0.878)

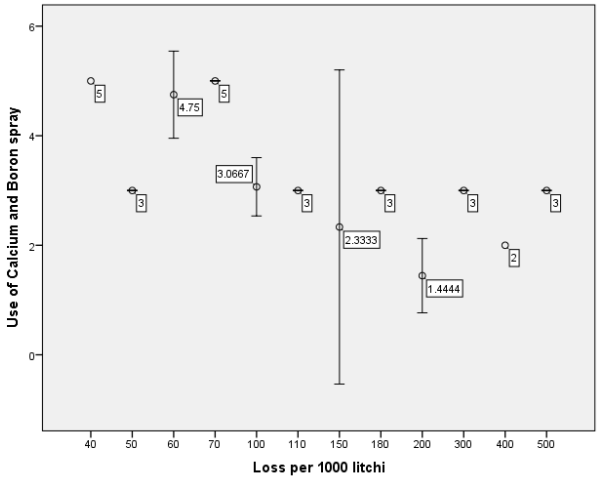


Figure 46 Correlation between loss per 1000 litchi and use of Calcium and Boron spray (Correlation coefficient value: -0.620)

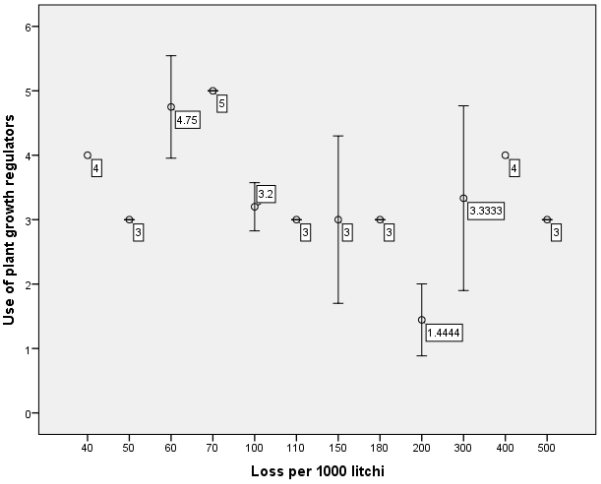


Figure 47 Correlation between loss per 1000 litchi and use of plant growth regulators Correlation coefficient value: -0.514

An increase of Calcium and Boron spray reduces the loss of money per 1000 Tk with a moderate negative correlation coefficient value of -0.595 (Figure 48). This data is similar to the previous correlation with a loss per 1000 litchi. Similarly, there is a moderate and negative correlation between the use of plant growth regulators and loss per 1000 Tk with a value of -0.564 (Figure 49). On the other hand picking harvesting method has shown a moderate negative correlation with a loss per 1000 litchi and loss per 1000 Tk with a value of -0.687 and-0.755, where the increasing frequency of handpicking harvesting method reduces the loss of money and fruit (Figure 50 and 51).

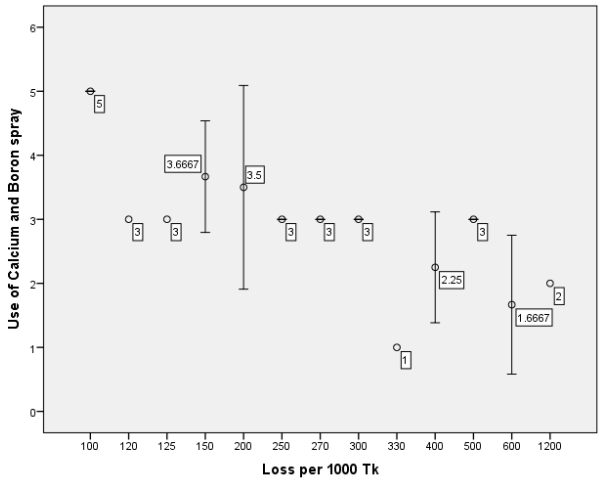


Figure 48 Correlation between loss per 1000 Tk and use of Calcium and Boron spray (Correlation coefficient value: -0.595)

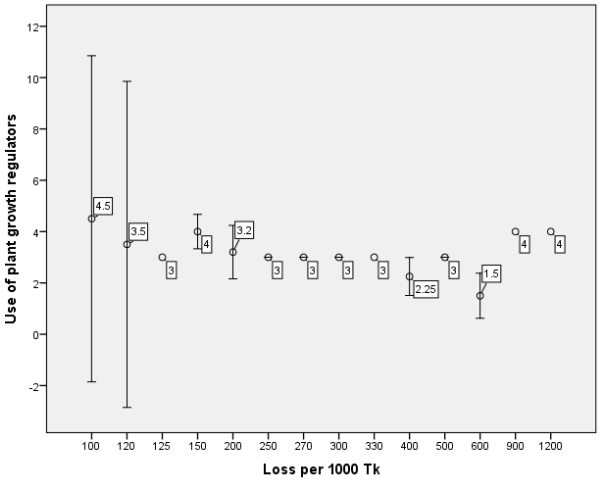


Figure 49 Correlation between loss per 1000 Tk and use of plant growth regulators (Correlation coefficient value: -0.564)

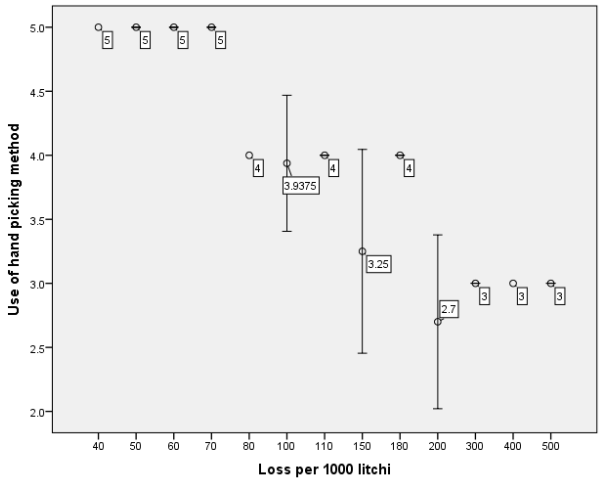


Figure 50 Correlation between loss per 1000 litchi and use of handpicking method (Correlation coefficient value: -0.687)

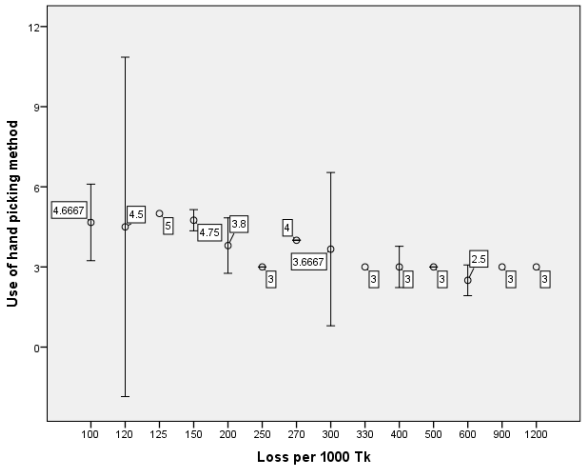


Figure 51 Correlation between loss per 1000 Tk and use of handpicking method (Correlation coefficient value: -0.755)

In the different part of the study has shown that increase in rank of knowledge of agrochemicals reduces the loss of lichi per 1000 and loss per 1000 Tk with a correlation value of -0.429 and -0.452 respectively (Figure 52 and 53). There is a moderate negative correlation among these variables. Furthermore, the ranking of environment-friendly packaging and loss per 1000 Tk shows a moderate negative correlation with a correlation coefficient value of -0.427 (Figure 54). Results show that increase awareness in agrochemicals and environmental packaging reduces loss in litchi.

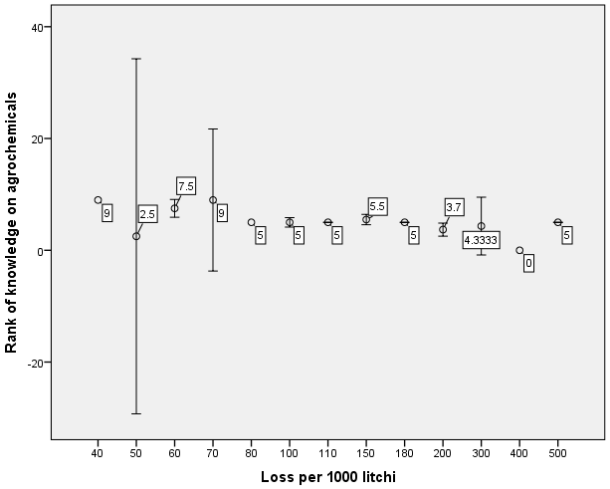


Figure 52 Correlation between loss per 1000 litchi and rank of knowledge on agrochemicals (Correlation coefficient value: -0.429)

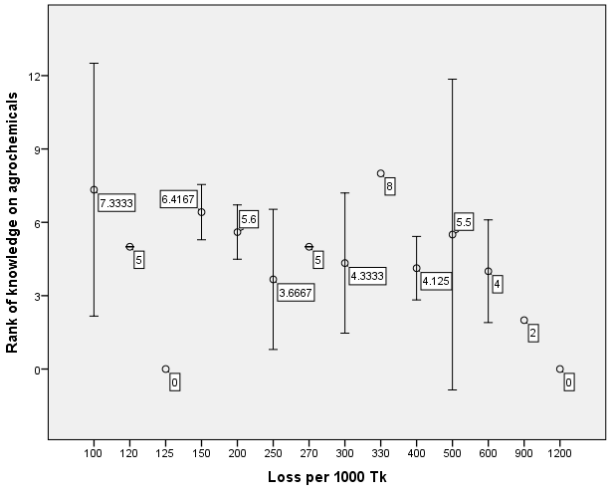


Figure 53 Correlation between loss per 1000 Tk and rank of knowledge on agrochemicals (Correlation coefficient value: -0.452)

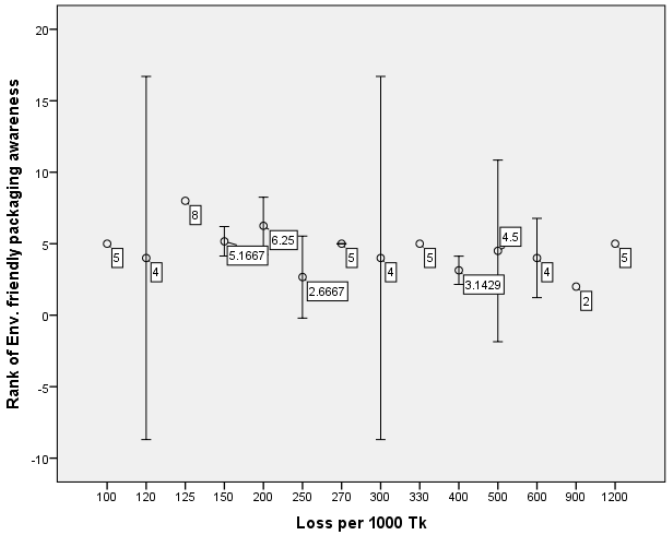


Figure 54 Correlation between loss per 1000 Tk and rank of env. friendly packaging awareness (Correlation coefficient value: -0.427)

Chapter 5
Discussion

As this is one of the few studies done on the litchi value chain in Dinajpur, a light was put on the litchi chain to discuss. In the first section, identification of stakeholders and their role was conducted and found that government and NGOs are not directly linked with the litchi chain. However, litchi producers are using their previous training from governments and NGOs to facilitate their production. BARI has been working on varieties and postharvest research for a long time, however, according to DAE varieties failed to show the expected result in the field. Most importantly, postharvest practice is not properly practised as the producers stated that they did not use modified atmosphere or LDPE packaging or temperature and moisture controlled vehicle for transportation in their practice and losses was 13.88% - 19.20% per 1000 litchi and 29.98% - 34.60% per 1000 Tk, which has similarities with the finding from a study by Molla *et al.* (2010) where he reported 16% loss. However, this study found out losses in different categories of farm sizes, which is 19.20% per 1000 litchi in the farm size larger than 0.75 ha and 34.60% per 1000 per Tk in farm size 0.50 to 0.75 ha. The larger farm produces more litchi and uses similar postharvest technology like a small and medium farm, which may have resulted in a more postharvest loss. Although in case of loss in 1000 Tk, medium-scale farm size has the highest loss, might be due to lower production than the large farm with higher investment compared to a small farm. It is noted that in the data collection period, it was difficult to find a medium-sized farm. This category was made on the author's own experience in the field as there was no exact information about the producers. It might be necessary for future research to correct categorising the farmers. Financial actors are helping the farmers in general, although specifically on litchi there are no activities. Getting financial help from the bank require legal documentation of the land and in that case, most of the litchi orchards are sold to the traders after flowering with a contract. The gender role study reveals that this sector is male-dominated and all the activities are controlled and benefited by the male community. This might be due to the land ownership in Bangladesh belongs to the male community. On the other hand, it is common to see women participate in litchi sorting, grading and packaging at the orchard in Dinajpur.

The litchi chain in Dinajpur is different from the chain found by Dewan *et al.* (2015) in Khagrachhari district, where Bepari, Faria was involved in the chain. In Dinajpur, it is sold to an Arat where Aratdar arranges the auction with a price and sell the litchi to Pikar. Then Pikar sells it to the retailer and the retailer sells it to the consumer. This is the traditional way of selling litchi in Dinajpur for many years. Due to the COVID-19 location of this Arat has been a change to a big field named Gore Shahid Boro Math. From this study it was noted that in 2021 production did not meet the target, however, profit from litchi was very high due to the Eid festival in the selling period of litchi. From the benefit-cost ratio, it was found that for Bombai litchi was 2.49, Bedana litchi was 6.49, Madraji litchi was 1.90 and China 2 litchi was 4.33. Akter *et al.* (2016) reported that for litchi production in Dinajpur Benefit-cost ratio is 1.93, which is not specified by the variety and the different selling prices of a different variety. In 2021, litchi B: C was higher as the Eid festival was at the harvesting time of litchi which increased the demand. Bedana litchi has a higher profit compared to any other litchi because of its higher pulp: seed ratio, size and quality, although production per tree is about more or less 2000-2500. On the other hand, the production of China 2 is 8000 per tree with a selling price of 4000 Tk per 1000 litchi, which maximise the profit. It can be observed that China 2 is more profitable in terms of production and profit, although, Bedana and Bomabai variety is preferred by the consumer for its quality. However, for analysing the cost and benefit for litchi, it was difficult to show the write data as, producer to producer it varies and in Arat selling price varies from morning to afternoon. This variation creates price fluctuation in the chain, however, Pikars are willing to pay a premium price for the quality litchi.

Litchi chain has a specific major strength, which is its regional characteristics helping the production, where major weakness prevails at production level. This year massive drop in production of Bombai litchi is noticed and it was reported by experts that the day-night temperature difference and changing

climate of this region is affecting this bearing habit of litchi. The demand and high profit of this litchi all over the country is one of the major opportunities. On the other hand, export potentialities are not significant enough as the GAP 2020 is recently release, where a lot of works need to be done to meet the export compliances (GAP, 2020). Food processing industries agree with the production status of litchi from Dinajpur and they are continuing their flavoured litchi drinks in the local and export market. Another major problem in the litchi production was found that the litchi fruit borer pest is destructive for the litchi. This drives the producers to invest a huge amount of money approximately 70000 Tk for more or equal to 7 times of spraying. A recent study by Islam *et al.* (2017) agreed with this pesticide application and reported the cause of death in children. However, DAE disagreed with the fact that pesticides were the major reason for the death. DAE claims that accumulating a huge number of the litchi by the young children may have caused this incident. Moreover, no storage facility, cold chain and postharvest practices preventing this fruit to add value. From the value share analysis of this chain, it can be seen that Pikar, Aratdar and retailers do not make much profit. As there is no postharvest management system for this, they have to sell this fresh litchi as soon as possible. In some cases, retailers have to sell their litchi at a low price in the market as litchi can not stay more than 3 days in normal condition and when it reaches the retail level it is already at the end of the postharvest life.

From the questionnaire survey, it was found that the majority of the producers rely on their self-experiences and agrochemical dealer's suggestions for their production practices. There is no training specifically for litchi and most of the producers did not take any training. On the other hand, producers are concerned about preharvest practices. They are using pesticides, Calcium and Boron spray and plant growth regulators to increase production and quality. In some cases, litchi tress does not bear flower or flower dropping occurs. This damages their production. Moreover, for preventing litchi borer producers find the excessive amount of pesticides as their one and only option. In harvesting, litchi is harvested by climbing the tree and using a ladder in the early morning. Immediately it is sorted and graded and packed in a bamboo basket or plastic crate. From authors research experience in litchi chain, it was noted that plastic crate was not used in packaging in the past year, although it is becoming popular among producers to supply litchi to the long distant places. Moreover, the recent distribution of plastic crates and awareness programmes from the DAE, DAM and HORTEX Foundation may have influenced the producers to use it. For filling the basket, it is traditional to pack the litchi with litchi leaves. Currently, the use of paper for packaging filling material is being noticed in the study. The use of plastic crates introduced the use of paper as a filling material in packaging. On the other hand, litchi is transported to the nearest Arat with an Auto van as it is cheap and accessible. Trucks and pick up vehicles are used to carry the litchi directly by the Pikar from the orchard to their main market. In previous year buses were used to carry the litchi to long distances. It is noted by the author that in the COVID-19 situation long-distance buses were stopped from operating, which might have increased the use of other mediums of transportation like trucks and pick up trucks. These vehicles got special permission stickers from DAM and DAE to transport food from one place to another.

Litchi producers reported that they are affected by postharvest losses. In the traditional system, litchi producers are forced to give 100 litchis per 1000 litchi free of cost which might be 300 Tk (2.97 €) loss (price is calculated on Bombai variety). This system helps the Pikar and retailers to compensate for their postharvest loss during transportation. However, producers have enough finance to invest in litchi pre and postharvest practices every year. Moreover, litchi producers also reported that they reinvest in their orchards every year. This is because litchi is an iconic business of Dinajpur and the demand is rising higher and higher every year. Producers are always interested in the litchi business.

Litchi producers reported that they have knowledge of agrochemicals, however, the knowledge level is not sufficient as they have rated their knowledge level lower and is not valid to state as a safe practice. This might be due to the absence of training in the litchi chain to promote good agricultural practices. The majority of their knowledge is based on their own experience and agrochemical dealer's suggestions. Producers are aware of biodiversity; however, their practice of agrochemicals contradict their statement. Their practice of agrochemicals does not follow any regulations and these practices

are not monitored by any authority. On the other hand, producers use an environment-friendly packaging system that is made of bamboo and the leaves of litchi (acquired during the harvesting). However, this bamboo basket does not meet the requirement of preventing postharvest loss. The recent adoption of the plastic crate is good news, although it is not enough to extend the postharvest life. It is found that correlations among knowledge of agrochemicals and environment-friendly packaging have a moderate negative correlation with the loss in the litchi chain. Moreover, Calcium and Boron spray showed a moderate positive correlation to mitigate the loss. From the author's observation, findings with correlation analysis showed some irregular outliers, which may have influenced the results. Further study with a large population size for finding a correlation with loss in litchi chain related to pre and postharvest practices may produce better results to interpret. Overall, litchi production in Dinajpur is profitable with a significant number of constraints. The government and NGOs are working to make this product recognised as a GI product. Agrofood processing company like PRAN Food Ltd. has a cool chain and properly certified processing industries to export processed food with proper value addition, however, the production of litchi failed to meet the local demand which blocks the possibility to enter the export market.

Chapter 6
Conclusions and recommendations

Litchi production in Dinajpur is profitable and full of future possibilities. This research reveals the potential actors in the chain and their roles. It is found that the Department of Agriculture has a well-structured governing body to help the farmers. However, collaboration among these departments is not significant. To answer the research question regarding the value chain of litchi it was found that litchi producers are the major actors in the chain, where Aratdar does the auction and Pikar does the wholesaling to sell to the retailers. Frequently, local consumers and local Pikar visit the orchard and buy the litchi directly. On the other hand, to illustrate the gender aspects, all the activities, access and control are for the male population, where women are majorly involved in litchi sorting, grading and packaging.

The major strength of this sector is that litchi is a regional product that has superior quality to any other litchi in the country. The constant high demand and the high market price is the main opportunities of this chain. Production of honey from litchi flower is a rising opportunity in this chain, which is beneficial for the environment and creating job opportunities for young entrepreneurs. The production practice of litchi is similar in more or less every farm and it is affected by various hindering factors. A large number of pesticide sprays are sprayed to the orchard to prevent litchi fruit borer, which damages this litchi fruit undeniably. There is no proper solution at the producer's hand to control this pest in an environment-friendly way. Furthermore, no flowering and flower dropping of litchi is common in production. Recent climate change in the Dinajpur region may have affected the bearing habit of litchi trees. Moreover, litchi producers have complained about the availability of quality litchi seedlings to get proper flowering and quality fruit quickly, where BARI developed varieties that failed to satisfy the yield target in Dinajpur. With these weaknesses, low production of litchi from the orchards is a major concern for the stakeholders in the litchi. Every year litchi chain struggles to meet the local demand, where it can be a major fruit for export. In litchi value share analysis, it was found that producers have 90.90% value share in the chain, where Pikar and retailers have 4.55% share each. The absence of processing and value addition prevented the other actors to gain higher value share.

Among the 50 litchi producers, there was no significant difference found in the practice of pre-harvest technology, however, it was noted that Calcium and Boron spray, use of plant growth regulators and pesticides are selected by the majority of respondents. Similarly, there was no significant difference found in postharvest practices among different farm sizes, where most of the producer follows the same method for each step in postharvest management. In harvesting, most of the respondents use handpicking and climbing tree methods to harvest the fruit. Moreover, they use the bamboo basket and plastic crate as the packaging with leaf and paper as filling material for the package. From farm to Arat, most of the litchi producers use the auto van to transport the litchi, where for long-distance truck and pick up truck is used.

Regarding the loss in the litchi chain, the majority of the respondents reported that they are affected by the postharvest loss which ranges from 13.88% to 19.20% per 1000 litchi, where loss per 1000 Tk ranges from 29.98% to 34.60%. On the economic assessment, it was found that there is a significant difference in investment in pre and postharvest technology depending on their farm sizes. Most of the producers stated that they have enough finance to invest in pre and postharvest technology and they have enough finance to reinvest. From the findings, it can be concluded that litchi producers are more concerned with production than postharvest management in Dinajpur.

In answering the barriers and reasons for using technology, easy access and price were the main factors stated by most of the producers. However, current technology is not significant enough to be considered as production and environment friendly, which caused uncertainty in production and no value addition in the chain. In contrast, change of price and accessibility of technology induces the use

of per and postharvest technology by the producers to form different farm sizes. Furthermore, on the environmental analysis, it was observed that litchi producers manage their waste by burning and they have stated that sufficient knowledge over agrochemicals, biodiversity and environment-friendly packaging. However, their ranking on the knowledge was 4 – 5 out of 10 scale, which is not significant enough to be considered as environment-friendly production.

Recommendations

This study is one of the few studies on the litchi value chain. To the authors best knowledge this value chain analysis of litchi is the first research on record. It is obvious to recommend further study with the findings of this research to mitigate the hindering factors. From the findings of this study, it was noted that producers were focused on increasing production through practice, where other actors also stated that there is a need for increased production to meet this demand. It is necessary to act on litchi production through good agricultural practices. Furthermore, improvement in postharvest management is required to increase the value addition of the available litchi at different stages of the value chain as from the findings it can be observed that the current packaging and transportation method is not suitable for better postharvest life. Therefore, specific recommendations to the commissioner, the department of Horticulture are stated as follows.

- Formulate research project to control litchi fruit borer with the minimum use of agrochemicals which will be in compliance with GAP 2020 and can be suitable to meet the export criteria and promote good agricultural practices among the producers
- Investigate the recent effect of day and night temperature difference on litchi flowering and come up with a possible immediate solution to prevent the irregular bearing habit of litchi in Dinajpur.
- Study on the regional variety and the BARI developed variety to find the best possible variety to meet the market demand and export criteria
- Improve and develop economic and environment-friendly postharvest management practice from the findings of this study which can be adopted by the stakeholder immediately for value addition in different stages of the value chain

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Annexes

Annex 1 Semi-structured interview checklist for key informants

Organisation/ individual	Interview checklist
1. Department of Horticulture, Hajee Mohammad Danesh Science and Technology University	1. What are the activities of this department? 2. What is the role of the Department of Horticulture in Litchi production, Dinajpur? 3. Who are the government and nongovernment collaborators of this department? 4. How does this collaboration work? 5. How profitable is the litchi production in Dinajpur? 6. What are the opportunities for the litchi producers? 7. What are the major constraints in litchi production? 8. What is the gender role in the chain? 9. What are the activities divided into gender? 10. What are access and control between male and female in litchi production?
2. Department of Agricultural Extension, Dinajpur	1. What are the extension activities of this department? 2. What is the role of the Department of Agricultural Extension in Litchi production, Dinajpur? 3. How many litchi producers are under this department? 4. What are the supports (financial or technical) provided to the litchi producers? 5. Who are the government and nongovernment collaborators of this department? 6. How does this collaboration work? 7. How profitable is the litchi production in Dinajpur? 8. What are the opportunities for the litchi producers? 9. What are the major constraints in litchi production? 10. What is the gender role in the chain? 11. What are the activities divided into gender? 12. What are access and control between male and female in litchi production?
3. Horticulture Centre, Dinajpur	1. What are the activities of this department?

	2. What is the role of the Horticulture Centre in Litchi production, Dinajpur? 3. How many litchi producers are in Dinajpur? 4. What are the supports (financial or technical) provided to the litchi producers? 5. What are the input supplies provided to the litchi producers? 6. What are the other input suppliers in the chain? 7. Who are the government and nongovernment collaborators of this department? 8. How does the collaboration work? 9. How profitable is the litchi production in Dinajpur? 10. What are the opportunities for the litchi producers? 11. What are the major constraints in litchi production? 12. What is the gender role in the chain? 13. What are the activities divided into gender? 14. What are access and control between male and female in litchi production?
4. Bangladesh Agricultural Research Institute	1. What are the activities of this research institute? 2. What are the major researches for litchi producers? 3. Who are the government and nongovernment collaborators of this department? 4. What is the acceptance rate of the research from this institute? 5. Why it is accepted or why it is rejected? 6. How does this collaboration work? 7. What are the opportunities for the litchi producers? 8. What are the major constraints in litchi production?
5. Department of Agricultural Marketing	1. What are the activities of this department? 2. What is the role of this department in Litchi production, Dinajpur? 3. What are the supports (financial or technical) provided to the litchi producers? 4. How many possible marketing channels in litchi production and what are they? 5. How the market information flows through the chain?

	6. Who are the government and nongovernment collaborators of this department? 7. How does this collaboration work? 8. How profitable is the litchi production in Dinajpur? 9. What is the retail price of 1000 litchi for purchasing among different stakeholders? 10. How the litchi market is controlled? 11. What are the government regulation for this chain? 12. What is the export potentiality of this sector? 13. What are the opportunities for the litchi producers? 14. What are the major constraints in litchi production?
6. Department of Agricultural Information	1. What are the activities of this department? 2. What is the role of this department in Litchi production, Dinajpur? 3. Who are the government and nongovernment collaborators of this department? 4. How does this collaboration work? 5. How the information flow among stakeholders and supporters in the chain? 6. How does this information flow help different supporters? 7. How this information flow can be improved? 8. What are the opportunities for the litchi producers? 9. What are the major constraints in litchi production?
7. Rajshahi Krishi Unnayan Bank	1. What is the role of this Bank in Litchi production, Dinajpur? 2. What are financial supports this bank provide to the litchi farmers? 3. What are the financial opportunities provided by this bank? 4. What are the major constraints for getting financial support? 5. Is there a difference in financial support based on gender? 6. If any what are these? If not, how it is helping both gender in the chain?
8. PRAN Food Ltd.	1. What are the activities of this company for litchi producers?

	2. Who are the government and nongovernment collaborators of this company? 3. How does this collaboration work? 4. What are the litchi products this company work on? 5. What is the price and profitability in these products? 6. What are the opportunities for the litchi producers? 7. What are the major constraints in litchi production? 8. What are the export potentialities by this company? 9. How it can be improved?
9. BRAC	1. What are the activities of this NGO? 2. How many litchi producers do you work? 3. Who are the government and nongovernment collaborators of this NGO? 4. How does this collaboration work? 5. How profitable is the litchi production in Dinajpur? 6. What are the opportunities for the litchi producers? 7. What are the major constraints in litchi production? 8. What is the gender role in the chain? 9. What are the activities divided into gender? 10. What are access and control between male and female in litchi production?
10. Litchi producers	1. What are major activities in litchi production? 2. What are the supports you receive from government and nongovernment organisation? 3. Who are your input suppliers? 4. Have you attended any training and workshops? 5. Do you use these training or workshops in your production? 6. If yes, how effective are these? If not, why? 7. What is the gender role in the chain? 8. What are the activities divided into gender? 9. What are access and control between male and female in litchi production? 10. What are the opportunities you think in this litchi sector?

	11. What are the major constraints in litchi production? 12. How profitable is litchi production? 13. What is the yield of your farm per season? 14. What is the variable cost for your production? 15. What is the profit/ revenue in this season? 16. What is the price of 1000 litchi you sell? 17. How available is market information to you?
11. Trader	1. What are major activities in trading litchi? 2. How this trading work? 3. What is the buying price of 1000 litchi from the farmers? 4. What is the selling price of 1000 litchi to others? 5. How profitable do you think is litchi trading? Why? 6. What are major opportunities do you think in this chain? 7. What are the major constraints you face in the chain? 8. How the market information helps you in trading?

Source: Author, 2021

Annex 2 Semi-structured questionnaire for litchi producers

ANALYSIS OF FACTORS AFFECTING THE POSTHARVEST LOSS IN LITCHI VALUE CHAIN, DINAJPUR

Van Hall Larenstein University of Applied Sciences
The Netherlands
2021

This questionnaire aims to find out the factors affecting the postharvest loss in Dinajpur region. This study is conducted for master's thesis at Van Hall Larenstein University of Applied Sciences under NUFFIC funding. Please coordinate the researcher through the questionnaire. Ask necessary questions for clarification.

1) What is your farm size?
    a) Less than 0.50 ha
    b) 0.50-.75 ha
    c) More than 0.75ha
2) Which category do you belong?
    a) Contract farmer
    b) Owner
    c) Others (Please specify) _____
3) How many litchi trees do you have in your orchard? (Estimated number)
    _____
4) How many litchi varieties do you have?
    _____
5) What are the varieties available in your litchi orchard? (Multiple selection)
    a) Bedana
    b) Madraji
    c) China 1
    d) China 2
    e) China 3
    f) Others (Please specify) _____
6) Have you received training on preharvest technology in litchi?
    a) Yes
    b) No
    A. If Yes, From where? (Multiple selection)
        a) Horticulture centre
        b) Department of Agricultural Extension
        c) NGOs
        d) Others (Please specify) _____
    (i) How satisfied are you with the training? (Multiple answers with check mark ✓)
        a) **Horticulture centre** (Very satisfied/ Satisfied/ Slightly satisfied/ Slightly not satisfied)
        b) **Department of Agricultural Extension** (Very satisfied/ Satisfied/ Slightly satisfied/ Slightly not satisfied)
        c) **NGOs** (Very satisfied/ Satisfied/ Slightly satisfied/ Slightly not satisfied)
        d) **Others** (Very satisfied/ Satisfied/ Slightly satisfied/ Slightly not satisfied)
    B. If No, can you specify the reason?
        _____
7) Do you use preharvest technology in your orchard?
    a) Yes

b) No

A. If Yes What are the preharvest technology do you use? (Multiple selection)

a. Fruit bagging
b. Netting
c. Calcium and Boron Spray (Prevention of fruit cracking)
d. Plant growth regulators
e. Pesticides
f. Others (Please specify) _____

(i) Rank the effectiveness of the treatment according to your experience? (Scale of 1-5; Multiple selection)

a. Fruit bagging_____
b. Netting_____
c. Calcium and Boron Spray (Prevention of fruit cracking) _____
d. Plant growth regulators_____
e. Pesticides_____
f. Others_____

(ii) How often do you use these preharvest treatments? (Multiple answers with check mark ✓)

a. **Fruit bagging** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
b. **Netting** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
c. **Calcium and Boron Spray** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
d. **Plant growth regulators** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
e. **Pesticides** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
f. **Others** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)

B. If No, please specify a reason

_____

8) Have you received training on postharvest technology in litchi?

a) Yes
b) No

A. If Yes, From where?

a. Horticulture centre
b. Department of Agricultural Extension
c. NGOs
d. Others (Please specify) _____)

(i) How satisfied are you with the training? (Multiple answers with check mark ✓)

b) **Horticulture centre** (Very satisfied/ Satisfied/ Slightly satisfied/ Slightly not satisfied)
c) **Department of Agricultural** Extension (Very satisfied/ Satisfied/ Slightly satisfied/ Slightly not satisfied)
d) **NGO**s (Very satisfied/ Satisfied/ Slightly satisfied/ Slightly not satisfied)
e) **Others** (Very satisfied/ Satisfied/ Slightly satisfied/ Slightly not satisfied)

B. If No, can you specify the reason?

_____

9) Do you use postharvest technology in your orchard?
   a) Yes
   b) No

If No, can you specify the reason?

_____

10) What are the harvesting methods do you use? (Multiple selection)
   a. Hand picking
   b. Using ladder
   c. Climbing tree
   d. Using machineries
   e. Others (Please specify) _____

11) Rank the effectiveness of harvesting methods: (Scale of 1-5; Multiple selection)
   a. Hand picking_____
   b. Using ladder _____
   c. Climbing tree _____
   d. Using machineries _____
   e. Others _____

12) How often do you use these harvesting methods? (Multiple answers with check mark ✓)
   a. **Hand picking** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
   b. **Using ladder** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
   c. **Climbing tree** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
   d. **Using machineries** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
   e. **Others** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)

13) What are the packaging methods do you use? (Multiple selection)
   a) Bamboo basket
   b) Corrugated paper cartoon box
   c) Plastic crate
   d) Modified atmosphere packaging
   e) LDPE (Low-density polyethylene) packaging
   f) None
   g) Others (Please specify)

14) Please rank the effectiveness of the packaging methods according to your experience: (Scale of 1-5; Multiple selection)
   a. Bamboo basket_____
   b. Corrugated paper cartoon box _____
   c. Plastic crate_____
   d. Modified atmosphere packaging_____
   e. LDPE (Low-density polyethylene) packaging _____
   f. Others _____

15) How often do you use these packaging methods? (Multiple answers with check mark ✓)
   a. **Bamboo basket (**Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
   b. **Corrugated paper cartoon box** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)

c. **Plastic crate** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
d. **Modified atmosphere packaging** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
e. **LDPE** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
f. **Others** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)

16) What are the package filling materials do you use? (Multiple selection)
a) Paper
b) Leaf
c) Polythene
d) None
e) Others (Please specify) _____

17) Please rank the effectiveness of the package filling material according to your experience: (Scale of 1-5; Multiple selection)
a) Paper _____
b) Leaf _____
c) Polythene _____
d) Others_____

18) How often do you use these package filling materials? (Multiple answers with check mark ✓)
a. **Paper (**Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
b. **Leaf** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
c. **Polythene** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
d. **Others** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)

19) What are the transportation methods do you use for litchi? (Multiple selection)
a) Auto van
b) Tricycle van
c) Truck
d) Bus
e) Motorcycle
f) Temperature and moisture-controlled vehicle
g) None
h) Others

20) Please rank the effectiveness of the transportation method according to your experience: (Scale of 1-5; Multiple selection)
a) Auto van_____
b) Tricycle van_____
c) Truck _____
d) Bus _____
e) Motorcycle _____
f) Temperature and moisture-controlled vehicle _____
g) Others _____

21) How often do you use these transportation methods? (Multiple answers with check mark ✓)
a. **Auto van (**Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)

b. **Tricycle van** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
c. **Truck** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
d. **Bus** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
e. **Motorcycle** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
f. **Temperature and moisture-controlled vehicle** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)
g. **Others** (Very infrequently/ Somewhat infrequently/ Occasionally/ Somewhat frequently/ Very frequently)

22) Are you affected by postharvest loss in litchi production?
a) Yes
b) No

23) How many litchis do you loss per 1000 litchi? (Estimation)
_____

24) How much money do you loss per 1000 litchi (Taka)?
_____

25) Do you have enough access to finance to invest in pre and postharvest technology?
a) Yes
b) No

If No, what are the reasons (Please specify)?
_____

26) How much money do you spend on preharvest management per season (Taka)?
…….

27) How much money do you spend on postharvest management per season (Taka)?
……

28) How satisfied are you with the cost, please rank on the scale of 1-5?
_____

29) Do you get enough money to reinvest in this pre and postharvest technology?
a) Yes
b) No

If No, please specify.
_____

30) Do you manage your waste material from preharvest and postharvest practice?
a) Yes
b) No

If Yes, how do you manage your waste?
a) Recycle
b) Dump in the trash
c) Burning
d) Burring in the soil
e) Others (Please specify) _____

If No, please specify the reason.
_____

31) Do you use agrochemicals in your orchard?

a) Yes
b) No

32) Do you have knowledge about the regulation of agrochemicals?
a) Yes
b) No

33) In what extend do you follow the regulation? Rank on scale of 1-10

_____

34) Are you concerned about biodiversity in your orchard?
a) Yes
b) No

35) How concern are you on the scale of 1-10

_____

36) Do you manage your pre and postharvest practices based on biodiversity in your orchard?
a) Yes
b) No

37) Are you concerned about environmentally friendly packaging?
a) Yes
b) No

38) How concern are you about environmentally friendly packaging on the scale of 1-10?

_____

39) What are the environmentally friendly packaging system do you use? (Please write)

_____

40) Do you have additional comment? (Please write)

_____

Thank you for your cordial participation
For further information or inquiry please contact by this address
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Source: Author, 2021

Annex 3 Harvard analytical tool for gender activity, access and role analysis

Production activities	Women	Men
Raising seedling		
Planting seedling		
Land preparation		
Fertiliser application		
Irrigation		
Pesticide application		
Training or pruning of branches		
Preharvest practices		
Harvesting		
Postharvest practices		

Resource	Access		Control	
	Women	Men	Women	Men
Land				
Seedling				
Fertiliser				
Irrigation water				
Pesticides				
Finance				
Labour				
Equipment				
Extension services				
Benefits				
Profit				
Power				
Respect				
Collaboration				
Reinvestment				

Source: Ludgate, 2016 and Author, 2021

Annex 4 List of key informants

Serial no.	Name	Position	Organisation/ individual	Type of organisation
1.	**Dr Shreef Mahmood**	**Professor**	**Department of Horticulture, Hajee Mohammad Danesh Science and Technology University**	Research university
2.	**Prodip Kumar Guha**	**Deputy director**	**Department of Agricultural Extension, Dinajpur**	Government
3.	**Mitul Kumar Saha**	**Assistant general manager**	**HORTEX Foundation**	Government
4.	**Shahadat Hossain**	**Scientific officer**	**Bangladesh Agricultural Research Institute**	Research institution
5.	**Reza Khan**	**Senor agricultural marketing officer**	**Department of agricultural marketing**	Government
6.	**Dr Saiful Islam**	**Project director**	**Department of Agricultural Information**	Government
7.	**Mahfuz Rubel**	**General officer**	**Rajshahi Krishi Unnayan Bank**	Government
8.	**Koushik Das**	**Assistant manager**	**PRAN Food Ltd.**	Private
9.	**Ismot Ara Begum**	**Area manager**	**BRAC**	NGO
10.	**Mosadeque Hossain**	**President**	**Alor Path e Jago Jubok**	Volunteer

Source: Author, 2021

Annex 5 Import and export data for litchi in M. tons

Export/ Import	2014-15 year	2015-16 year	2016-17 year	2017-18 year	2018-19 year
Import	10.908	6.92	6.76	-	1.160
Export	74.17	0.035	0.100	1.932	-

Source: Plant quarantine wing (DAE), 2021

Annex 6 One-way ANOVA test with LSD Post Hoc multiple comparison test at P ≤ 0.05

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Number of trees	Between Groups	264326.507	2	132163.253	24.689	.000
	Within Groups	251601.493	47	5353.223		
	Total	515928.000	49			
Number of varieties	Between Groups	30.327	2	15.163	18.000	.000
	Within Groups	39.593	47	.842		
	Total	69.920	49			
Loss per 1000	Between Groups	20234.667	2	10117.333	.939	.398
	Within Groups	506317.333	47	10772.709		
	Total	526552.000	49			
Loss per 1000 tk	Between Groups	20076.500	2	10038.250	.198	.821
	Within Groups	2379884.000	47	50635.830		
	Total	2399960.500	49			
Money spend on preharvest	Between Groups	8.848E+10	2	4.424E+10	22.530	.000
	Within Groups	9.229E+10	47	1963667518		
	Total	1.808E+11	49			
Money spend on postharvest	Between Groups	1.613E+10	2	8063532100	16.119	.000
	Within Groups	2.351E+10	47	500241191.5		
	Total	3.964E+10	49			

Annex 7 KW test results where P ≤ 0.05

Test Statistics[a,b]

	Use of bamboo basket	Use of plastic crate	Effectiveness of leaf	Use of leaf	Ranking of auto van	Use of auto van
Chi-Square	8.992	6.816	6.370	6.000	12.698	18.107
df	2	2	2	2	2	2
Asymp. Sig.	.011	.033	.041	.050	.002	.000

a. Kruskal Wallis Test

b. Grouping Variable: Farm size

Annex 8 LSD test results where P ≤ 0.05

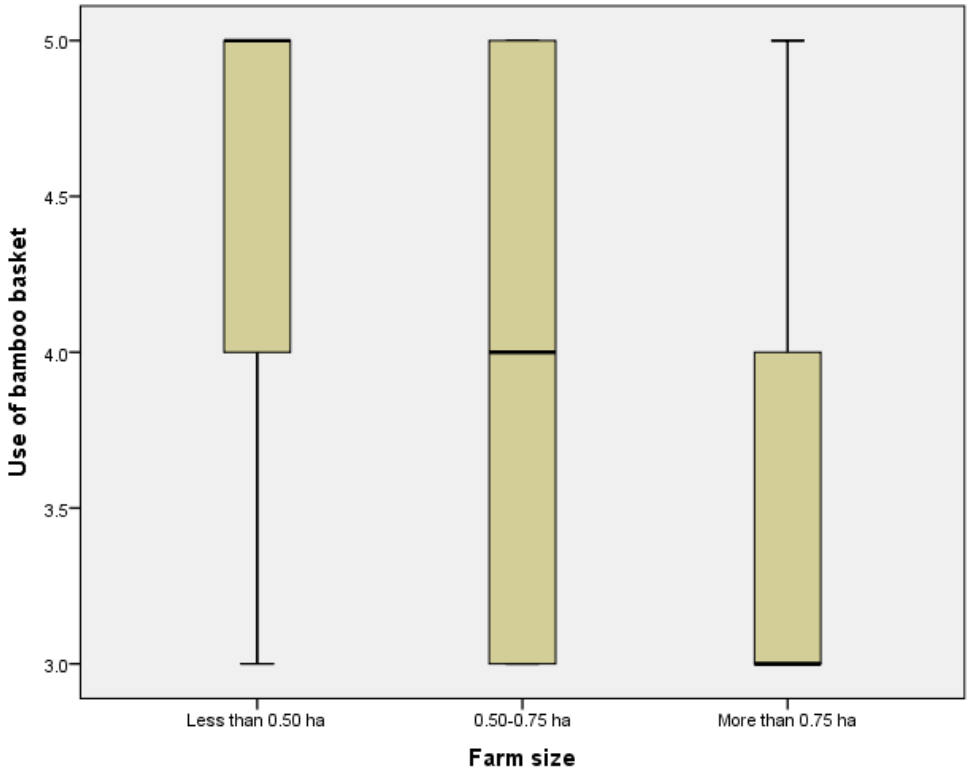
Multiple Comparisons

LSD

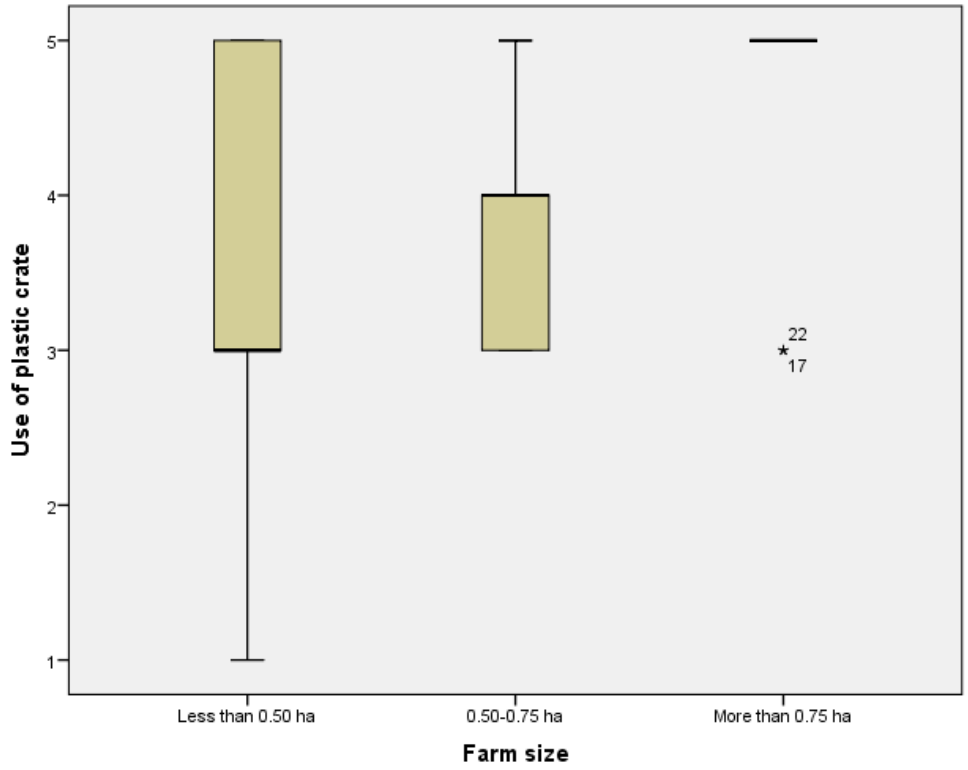
Dependent Variable	(I) Farm size	(J) Farm size	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Number of trees	Less than 0.50 ha	0.50-0.75 ha	-34.027	23.896	.161	-82.10	14.05
		More than 0.75 ha	-190.760*	27.376	.000	-245.83	-135.69
	0.50-0.75 ha	Less than 0.50 ha	34.027	23.896	.161	-14.05	82.10
		More than 0.75 ha	-156.733*	29.870	.000	-216.82	-96.64
	More than 0.75 ha	Less than 0.50 ha	190.760*	27.376	.000	135.69	245.83
		0.50-0.75 ha	156.733*	29.870	.000	96.64	216.82
Number of varieties	Less than 0.50 ha	0.50-0.75 ha	-.627*	.300	.042	-1.23	-.02
		More than 0.75 ha	-2.060*	.343	.000	-2.75	-1.37
	0.50-0.75 ha	Less than 0.50 ha	.627*	.300	.042	.02	1.23
		More than 0.75 ha	-1.433*	.375	.000	-2.19	-.68
	More than 0.75 ha	Less than 0.50 ha	2.060*	.343	.000	1.37	2.75
		0.50-0.75 ha	1.433*	.375	.000	.68	2.19
Loss per 1000	Less than 0.50 ha	0.50-0.75 ha	-13.867	33.898	.684	-82.06	54.33
		More than 0.75 ha	-53.200	38.835	.177	-131.33	24.93
	0.50-0.75 ha	Less than 0.50 ha	13.867	33.898	.684	-54.33	82.06
		More than 0.75 ha	-39.333	42.373	.358	-124.58	45.91
	More than 0.75 ha	Less than 0.50 ha	53.200	38.835	.177	-24.93	131.33
		0.50-0.75 ha	39.333	42.373	.358	-45.91	124.58
Loss per 1000 tk	Less than 0.50 ha	0.50-0.75 ha	-46.200	73.493	.533	-194.05	101.65
		More than 0.75 ha	-20.200	84.196	.811	-189.58	149.18
	0.50-0.75 ha	Less than 0.50 ha	46.200	73.493	.533	-101.65	194.05
		More than 0.75 ha	26.000	91.866	.778	-158.81	210.81
	More than 0.75 ha	Less than 0.50 ha	20.200	84.196	.811	-149.18	189.58
		0.50-0.75 ha	-26.000	91.866	.778	-210.81	158.81
Money spend on preharvest	Less than 0.50 ha	0.50-0.75 ha	-21946.667	14472.659	.136	-51061.90	7168.57
		More than 0.75 ha	-110680.000*	16580.514	.000	-144035.69	-77324.31
	0.50-0.75 ha	Less than 0.50 ha	21946.667	14472.659	.136	-7168.57	51061.90
		More than 0.75 ha	-88733.333*	18090.824	.000	-125127.38	-52339.29
	More than 0.75 ha	Less than 0.50 ha	110680.000*	16580.514	.000	77324.31	144035.69
		0.50-0.75 ha	88733.333*	18090.824	.000	52339.29	125127.38
Money spend on postharvest	Less than 0.50 ha	0.50-0.75 ha	-9780.000	7304.729	.187	-24475.22	4915.22
		More than 0.75 ha	-47300.000*	8368.618	.000	-64135.49	-30464.51
	0.50-0.75 ha	Less than 0.50 ha	9780.000	7304.729	.187	-4915.22	24475.22
		More than 0.75 ha	-37520.000*	9130.911	.000	-55889.02	-19150.98
	More than 0.75 ha	Less than 0.50 ha	47300.000*	8368.618	.000	30464.51	64135.49
		0.50-0.75 ha	37520.000*	9130.911	.000	19150.98	55889.02

*. The mean difference is significant at the 0.05 level.

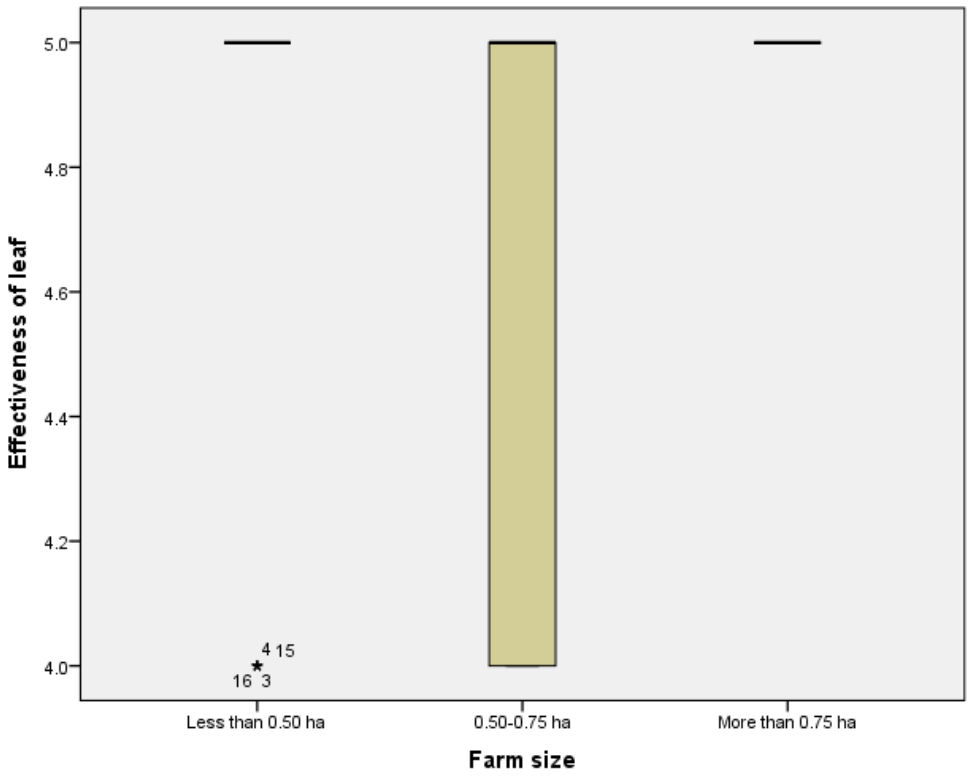
Annex 9 Boxplot with bamboo basket packaging use and different farm sizes



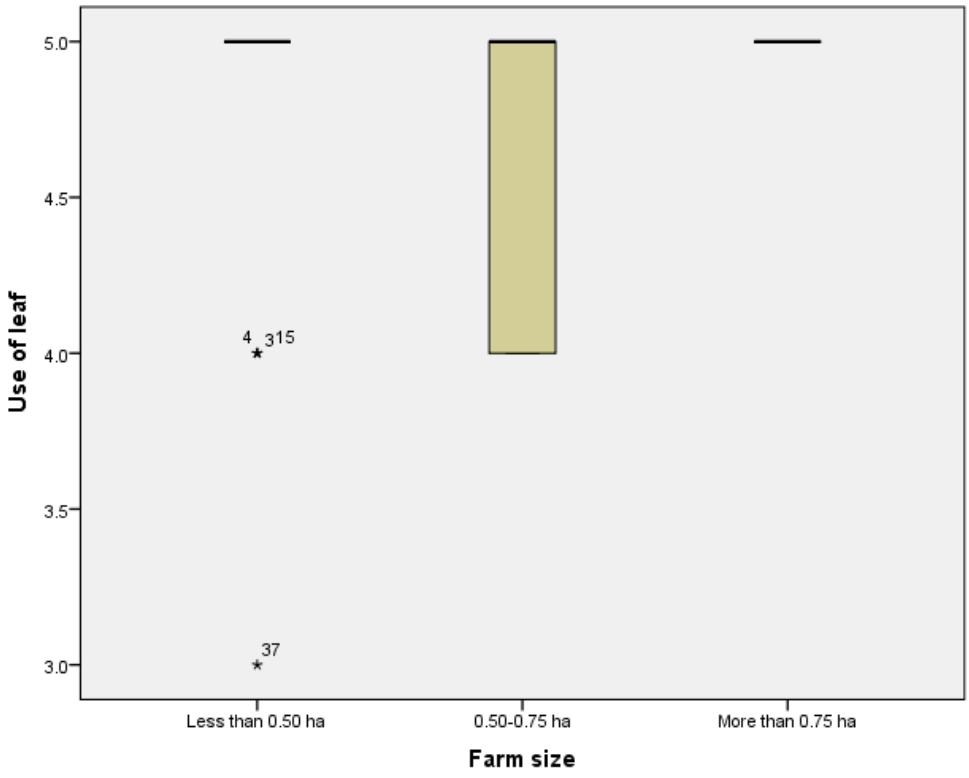
Annex 10 Boxplot with plastic crate packaging use and different farm sizes



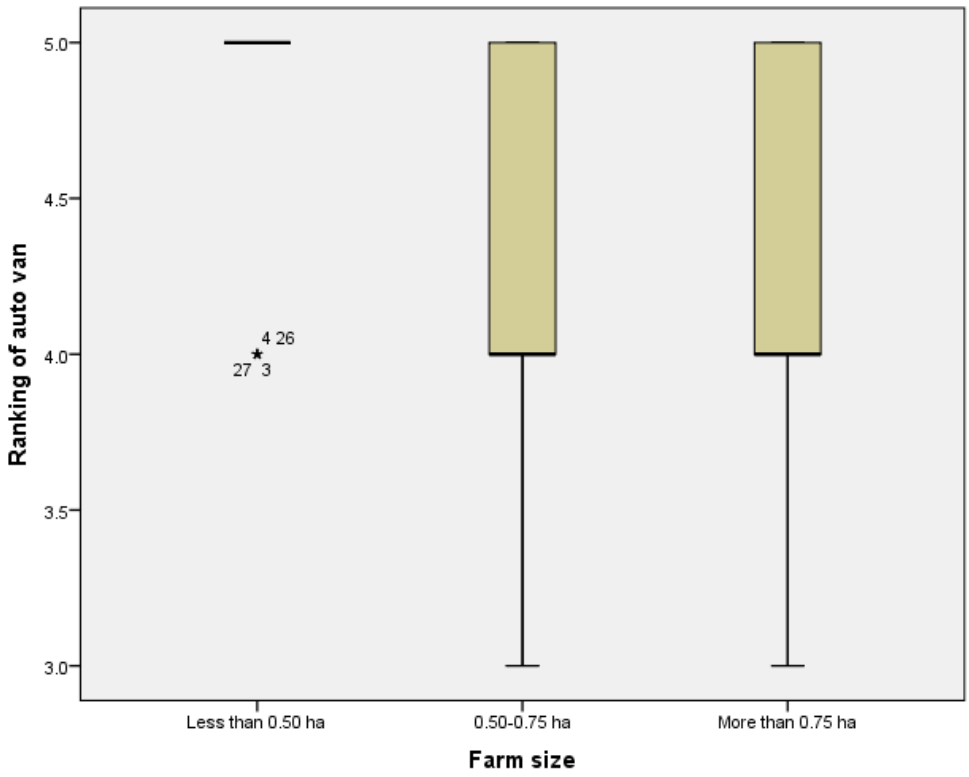
Annex 11 Boxplot with filling material leaf effectiveness and different farm sizes



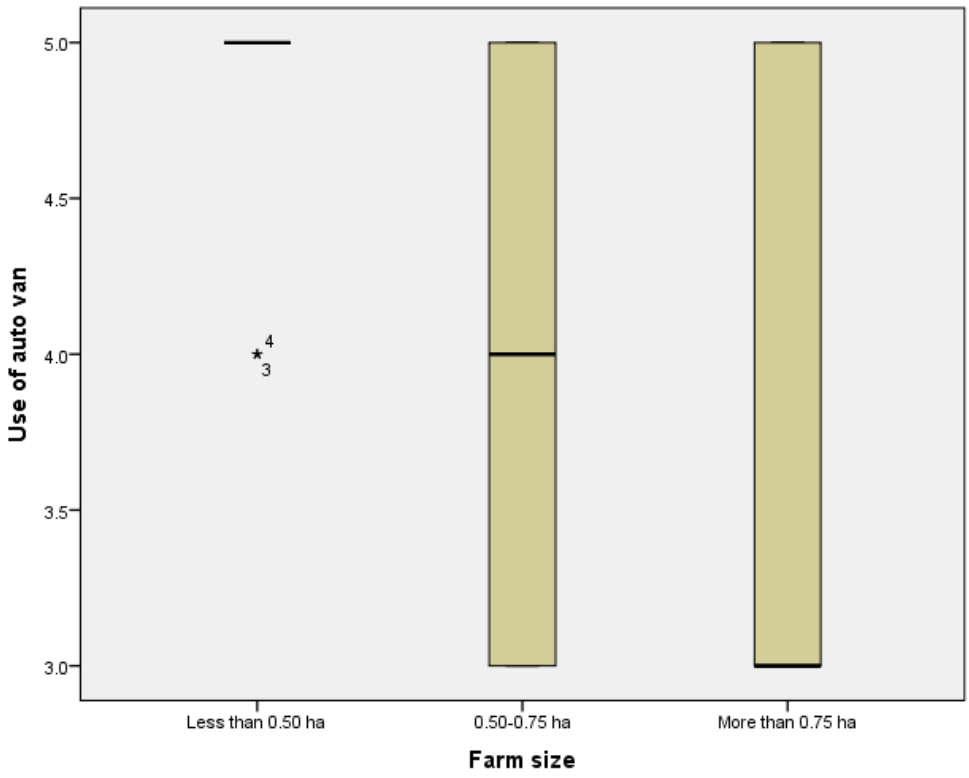
Annex 12 Boxplot with filling material leaf use and different farm sizes



Annex 13 Boxplot with transportation auto van ranking and different farm sizes



Annex 14 Boxplot with transportation auto van use and different farm sizes



Annex 15 Correlation matrix

Correlations

			Loss per 1000 litchi	Loss per 1000 Tk	Money spend on preharvest (Tk)	Money spend on postharvest (Tk)	Use of netting	Use of Calcium and Boron spray	Use of palnt growth regulators	Use of hand picking	Use of climbing tree method	Use of plastic crate	Use of auto van	Use of truck	Use of motorcycle	Use of paper	Use of leaf	Rank biodiversity	Rank of knowledge on agrochemicals	Rank of Env. friendly packaging
Spearman's rho	Loss per 1000 litchi	Correlation Coefficient	1.000	.824**	.188	.156	-.545*	-.620**	-.514**	-.687**	-.001	-.070	-.082	.079	-.569	.284	.031	-.381*	-.429**	-.168
		Sig. (2-tailed)	.	.000	.190	.278	.036	.000	.000	.000	.996	.667	.590	.739	.068	.098	.830	.032	.002	.315
		N	50	50	50	50	15	45	47	50	43	40	45	20	11	35	50	32	50	38
	Loss per 1000 Tk	Correlation Coefficient	.824**	1.000	.184	.252	-.485	-.595**	-.564**	-.755**	.089	-.110	.111	-.189	-.489	.275	.249	-.588**	-.452**	-.427**
		Sig. (2-tailed)	.000	.	.202	.077	.067	.000	.000	.000	.570	.501	.467	.425	.127	.110	.082	.000	.001	.008
		N	50	50	50	50	15	45	47	50	43	40	45	20	11	35	50	32	50	38
	Money spend on preharvest (Tk)	Correlation Coefficient	.188	.184	1.000	.870**	.107	-.042	-.039	-.270	.355*	.361*	-.320*	.632**	-.347	.338*	.233	-.284	.150	.141
		Sig. (2-tailed)	.190	.202	.	.000	.705	.782	.797	.058	.019	.022	.032	.003	.296	.047	.104	.115	.298	.397
		N	50	50	50	50	15	45	47	50	43	40	45	20	11	35	50	32	50	38
	Money spend on postharvest (Tk)	Correlation Coefficient	.156	.252	.870**	1.000	.407	.022	-.037	-.255	.370*	.449**	-.119	.607**	-.693*	.339*	.440**	-.474**	.333*	.072
		Sig. (2-tailed)	.278	.077	.000	.	.132	.885	.807	.074	.015	.004	.436	.005	.018	.046	.001	.006	.018	.668
		N	50	50	50	50	15	45	47	50	43	40	45	20	11	35	50	32	50	38
	Use of netting	Correlation Coefficient	-.545*	-.485	.107	.407	1.000	.931**	.751**	.209	.968**	.252	.527	.	-.111	.	.494	.	.622*	-.167
		Sig. (2-tailed)	.036	.067	.705	.132	.	.000	.002	.455	.000	.547	.064	.	.760	.	.061	.	.013	.645
		N	15	15	15	15	15	13	14	15	9	8	13	1	10	9	15	11	15	10
	Use of Calcium and Boron spray	Correlation Coefficient	-.620**	-.595**	-.042	.022	.931**	1.000	.822**	.665**	-.018	.133	.055	.091	.	.188	-.043	.427*	.554**	.247
		Sig. (2-tailed)	.000	.000	.782	.885	.000	.	.000	.000	.915	.427	.727	.703	.	.296	.781	.021	.000	.159
		N	45	45	45	45	13	45	44	45	39	38	42	20	8	33	45	29	45	34
	Use of palnt growth regulators	Correlation Coefficient	-.514**	-.564**	-.039	-.037	.751**	.822**	1.000	.617**	-.009	.267	-.089	.308	-.667*	.069	-.001	.578**	.522**	.200
		Sig. (2-tailed)	.000	.000	.797	.807	.002	.000	.	.000	.955	.105	.571	.187	.035	.704	.996	.001	.000	.241
		N	47	47	47	47	14	44	47	47	40	38	43	20	10	33	47	31	47	36
	Use of hand picking	Correlation Coefficient	-.687**	-.755**	-.270	-.255	.209	.665**	.617**	1.000	-.219	.106	-.193	.236	.265	.000	-.278	.679**	.422**	.594**
		Sig. (2-tailed)	.000	.000	.058	.074	.455	.000	.000	.	.159	.516	.204	.316	.432	1.000	.051	.000	.002	.000
		N	50	50	50	50	15	45	47	50	43	40	45	20	11	35	50	32	50	38
	Use of climbing tree method	Correlation Coefficient	-.001	.089	.355*	.370*	.968**	-.018	-.009	-.219	1.000	-.082	.406*	.205	-.775	-.286	.369*	-.355	-.008	-.359*
		Sig. (2-tailed)	.996	.570	.019	.015	.000	.915	.955	.159	.	.619	.010	.385	.070	.132	.015	.075	.960	.043
		N	43	43	43	43	9	39	40	43	43	39	39	20	6	29	43	26	43	32
	Use of plastic crate	Correlation Coefficient	-.070	-.110	.361*	.449**	.252	.133	.267	.106	-.082	1.000	-.281	-.079	-1.000**	.376*	.032	.089	.648**	.105
		Sig. (2-tailed)	.667	.501	.022	.004	.547	.427	.105	.516	.619	.	.092	.742	.	.040	.842	.665	.000	.573
		N	40	40	40	40	8	38	38	40	39	40	37	20	5	30	40	26	40	31
	Use of auto van	Correlation Coefficient	-.082	.111	-.320*	-.119	.527	.055	-.089	-.193	.406*	-.281	1.000	-.861**	-.316	-.264	.425**	-.615**	-.160	-.823**
		Sig. (2-tailed)	.590	.467	.032	.436	.064	.727	.571	.204	.010	.092	.	.000	.407	.131	.004	.000	.293	.000
		N	45	45	45	45	13	42	43	45	39	37	45	17	9	34	45	30	45	33
	Use of truck	Correlation Coefficient	.079	-.189	.632**	.607**	.	.091	.308	.236	.205	-.079	-.861**	1.000	.	.164	.	.353	.042	.755**
		Sig. (2-tailed)	.739	.425	.003	.005	.	.703	.187	.316	.385	.742	.000	.	.	.544	.	.197	.862	.000
		N	20	20	20	20	1	20	20	20	20	20	17	20	0	16	20	15	20	18
	Use of motorcycle	Correlation Coefficient	-.569	-.489	-.347	-.693*	-.111	.	-.667*	.265	-.775	-1.000**	-.316	.	1.000	.	.000	.	.	.000
		Sig. (2-tailed)	.068	.127	.296	.018	.760	.	.035	.432	.070	.	.407	.	.	.	1.000	.	.	1.000
		N	11	11	11	11	10	8	10	11	6	5	9	0	11	9	11	11	11	11
	Use of paper	Correlation Coefficient	.284	.275	.338*	.339*	.	.188	.069	.000	-.286	.376*	-.264	.164	.	1.000	.000	-.071	.303	.126
		Sig. (2-tailed)	.098	.110	.047	.046	.	.296	.704	1.000	.132	.040	.131	.544	.	.	1.000	.714	.077	.493
		N	35	35	35	35	9	33	33	35	29	30	34	16	9	35	35	29	35	32
	Use of leaf	Correlation Coefficient	.031	.249	.233	.440**	.494	-.043	-.001	-.278	.369*	.032	.425**	.	.000	.000	1.000	-.608**	.000	-.330*
		Sig. (2-tailed)	.830	.082	.104	.001	.061	.781	.996	.051	.015	.842	.004	.	1.000	1.000	.	.000	1.000	.043
		N	50	50	50	50	15	45	47	50	43	40	45	20	11	35	50	32	50	38
	Rank biodiversity	Correlation Coefficient	-.381*	-.588**	-.284	-.474**	.	.427*	.578**	.679**	-.355	.089	-.615**	.353	.	-.071	-.608**	1.000	.335	.697**
		Sig. (2-tailed)	.032	.000	.115	.006	.	.021	.001	.000	.075	.665	.000	.197	.	.714	.000	.	.061	.000
		N	32	32	32	32	11	29	31	32	26	26	30	15	11	29	32	32	32	31
	Rank of knowledge on agrochemicals	Correlation Coefficient	-.429**	-.452**	.150	.333*	.622*	.554**	.522**	.422**	-.008	.648**	-.160	.042	.	.303	.000	.335	1.000	.315
		Sig. (2-tailed)	.002	.001	.298	.018	.013	.000	.000	.002	.960	.000	.293	.862	.	.077	1.000	.061	.	.054
		N	50	50	50	50	15	45	47	50	43	40	45	20	11	35	50	32	50	38
	Rank of Env. friendly packaging	Correlation Coefficient	-.168	-.427**	.141	.072	-.167	.247	.200	.594**	-.359*	.105	-.823**	.755**	.000	.126	-.330*	.697**	.315	1.000
		Sig. (2-tailed)	.315	.008	.397	.668	.645	.159	.241	.000	.043	.573	.000	.000	1.000	.493	.043	.000	.054	.
		N	38	38	38	38	10	34	36	38	32	31	33	18	11	32	38	31	38	38

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).