A Study of the Mango Supply Chain with an Emphasis on Orchard Operations

THESIS

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By

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2023

CERTIFICATE

This is to certify that the thesis titled - **A Study of the Mango Supply Chain with an Emphasis on Orchard Operations** submitted by **Jagarlapudi Krishna Manasvi** ID No **2019PHXF0036P** for award of Ph.D. of the Institute embodies original work done by her under my supervision.

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This research work and study was only possible with the unending interviews and interactions I did with the farmers, contractors, and horticulture officials of the three districts of the state of Telangana. The ground-level insights and pointers were highly critical in helping me understand the entire mango supply chain. They led me to discover new gaps in the existing

functioning of the farming system. During my data collection, I contacted and interacted with more than 330 farmers who welcomed me wholeheartedly to their farm and explained the entire mango orchard farming in laymen's terms. Most farmers interacted multiple times and were as curious about the research as I was. They are true heroes of the thesis and the future of farming in India.

Krishna Manasvi J.

ABSTRACT

Mango is one of the most cultivated fruits in India, and understanding mango orchard operations can improve the supply chain. The purpose of this research on the mango supply chain, focusing on orchard operations in India, is to identify the factors influencing harvest quantity, quality, and supply chain losses. The research was conducted in the Telangana districts of Jangaon, Rangareddy, and Yadadri Bhuvanagiri. Face-to-face interviews with farmers, hired managers, and pre-harvest contractors were undertaken to gather information regarding mango orchard operations. A structured survey was developed based on the information acquired from the interviews and extensive literature review, and 332 responses were collected. After cleaning the collected data, multiple regression was selected as the most appropriate strategy for analysis. The significant factors identified by the regression results were used as a basis for the Design of Experiments. This method helps determine the factor effect and interaction effect on response variables.

Pre-harvest losses refer to the proportion of mangoes lost between the stages of fruit set to early maturity. This study established a conceptual framework for determining the factors influencing pre-harvest losses. Fifteen potential factors were selected based on the literature review and expert interviews. The initial regression model revealed that pre-harvest losses were influenced by experience in orchard operations, orchard type (marginal and small), orchard management, district (Jangaon), and pesticide application frequency. The interaction effects of orchard management and orchard type, pesticide application frequency and orchard management, orchard management and orchard operations experience, pesticide application frequency and orchard type, and orchard type and orchard operations experience were identified as significant using the design of experiments.

Overripe fruits are lost due to harvest losses due to poor planning. The research presents a conceptual framework based on ten factors identified through literature analysis and in-depth

interviews with horticulture experts. The study studied harvest loss factors like experience in mango orchard management, pesticide application frequency, and the number of picking cycles. The research also revealed the interaction effect of harvest loss factors, including the number of picking cycles and orchard operating experience, the number of picking cycles and pesticide application frequency, pesticide application frequency, and orchard operations.

The visual appearance typically determines mango quality, and in this study, the size of the mangoes was utilized to measure their quality. The factor and interaction impacts of several parameters on mango quality, such as the number of picking cycles, fertilizer cost, fertilizer variety, pesticide variety, and pesticide application frequency, were investigated. To establish their cumulative impact on mango quality, the study examined the impact of these factors on mango quality as well as their interactions with one another.

Many factors influence mango harvest quantity, including the number of picking cycles, experience in orchard operations, cost of fertilizer application, and orchard type. The factor interaction between experience in orchard operations and cost of fertilizer application, experience in orchard operations and orchard type, number of picking cycles and cost of fertilizer application, number of picking cycles and orchard type, and orchard type and cost of fertilizer application significantly impacted mango harvest quantity.

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1 CHAPTER: INTRODUCTION

This chapter provides an overview of the study. The chapter is divided into seven sections. The first section provides an outline of the study's background. Next, mango orchard operations are presented. The research questions and objectives for this study are provided in the following sections. Following that, the scope of this study and the motivation for this study is stated. Finally, a brief outline thesis and conclusion to this introductory chapter are presented. Figure 1 depicts a visual overview of this chapter.

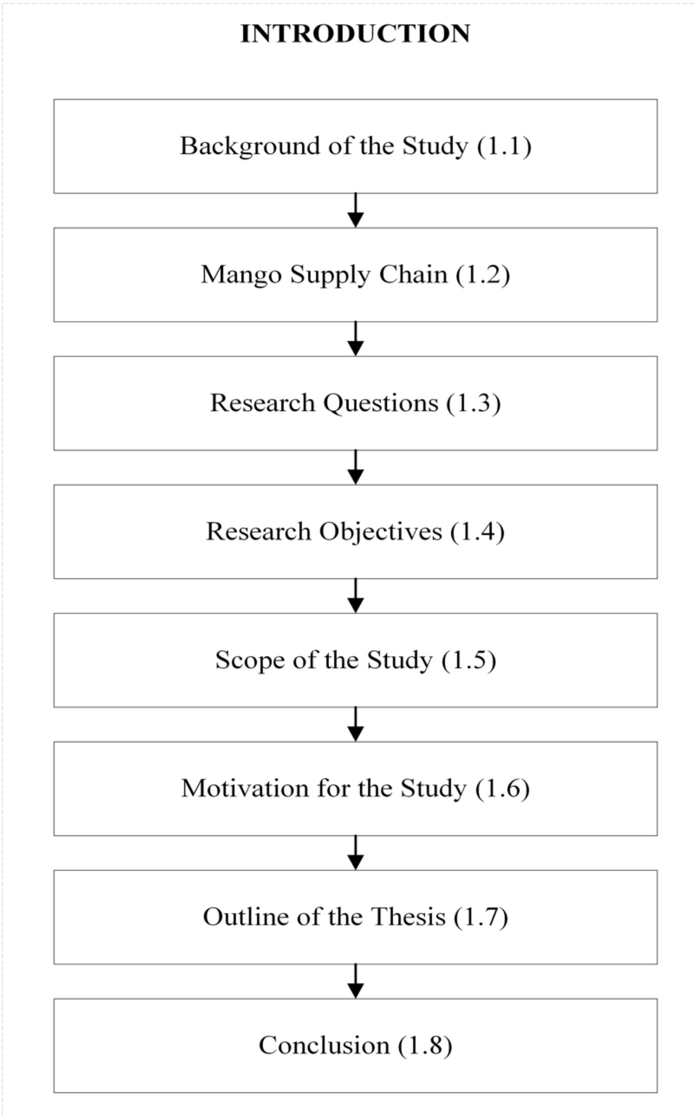


Figure 1 Overview of Chapter 1

1.1 Background of Study

According to Food and Agriculture Organization, Horticulture is the field of plant agriculture that focuses on garden crops, fruits, vegetables, and ornamental plants. This term comes from the Latin words hortus, which means "garden," and colere, which means "to cultivate." In India, more than 90 percent of the country's horticultural output comprises fruits and vegetables. India is the second largest producer of fruits and vegetables worldwide and the leader in several horticultural crops, including mango, banana, papaya, cashew nut, areca nut, potato, and okara (FAO, 2018). India is the largest producer of mango, mangosteen, and guava, followed by Indonesia and Mexico, with a harvest quantity of 24.7 million tonnes and a 45.14 percent world market share (FAO, 2020). Mango contributes significantly to India's exports of fresh and processed horticultural products to the United Arab Emirates, the United Kingdom, Qatar, Oman, and Kuwait. In 2021–2022, the country exported 27.8 thousand metric tonnes of fresh mangoes and 123.5 thousand metric tonnes of mango pulp, valuing 44 million and 124 million USD, respectively (APEDA, 2021).

The agricultural output value of mango, mangosteen, and guava in India is 20.2 million USD, compared to 9.6 million USD and 1.84 million USD for banana and papaya, respectively (FAO, 2020). Mangoes are grown in about a thousand varieties in India, with the essential commercial types being Alphonso, Banganapalli, Chausa, Dashehri, Langda, Totapuri, and Kesar. The Indian states of Uttar Pradesh, Andhra Pradesh, Karnataka, Bihar, and Telangana are significant mango producers. We conducted this study in Telangana, which ranks seventh in mango production (Figure 2). Telangana has 33 districts, 32 producing mangoes on 31.7 thousand acres, yielding 1.27 million metric tonnes. Commercial mango types grown in Telangana include Banganapalli, Suvarnarekha, Neelum, and Totapuri. The largest mango-producing districts are Jagtial, Khammam, Nagarkurnool, Rangareddy, and Mancherial (APEDA, 2021).

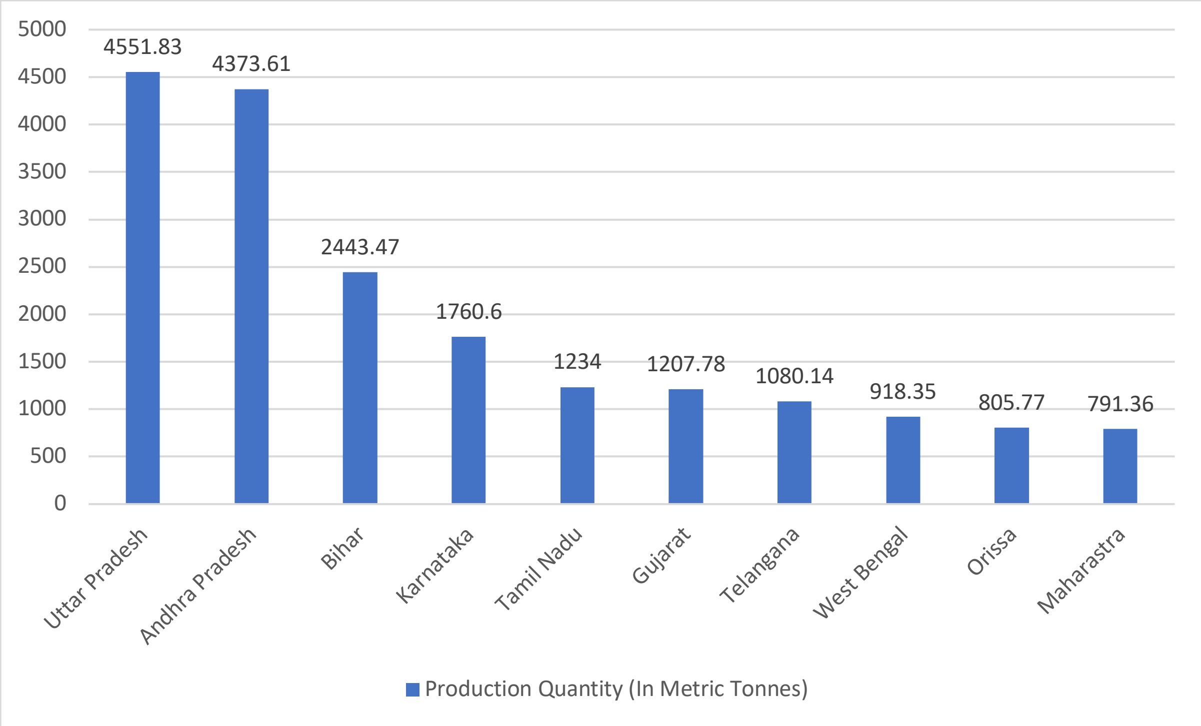


Figure 2 Major Mango-Producing States in India

The Government of India's Ministry of Agriculture and Farmer's Welfare classifies Indian farmers into five categories based on their land area. Orchard types are marginal, small, semi-medium, medium, and large, as shown in Figure 3 (Ministry of Agriculture and Farmers Welfare, 2019). In the study area, 80 percent of the farmers are marginal, 12 percent are small, 6 percent are semi-medium, and 2 percent are medium (Figure 4). Most farmers own marginal-sized orchards, so we have focused our study on them.

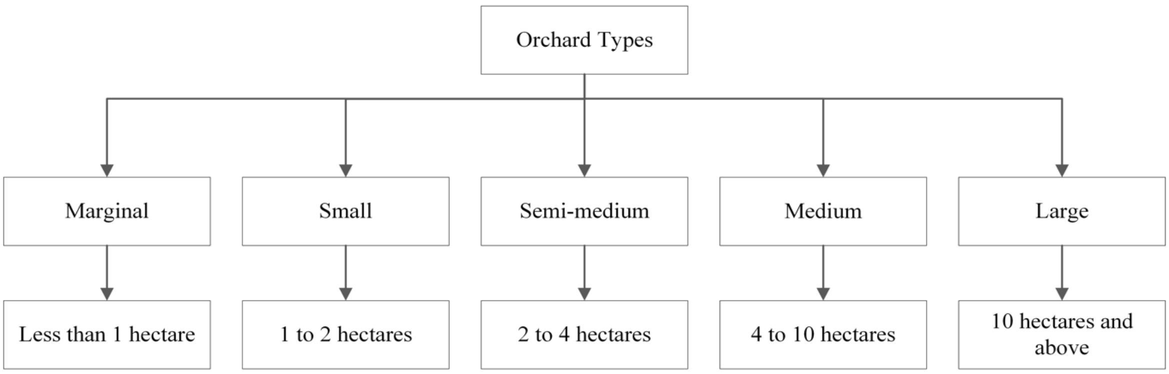
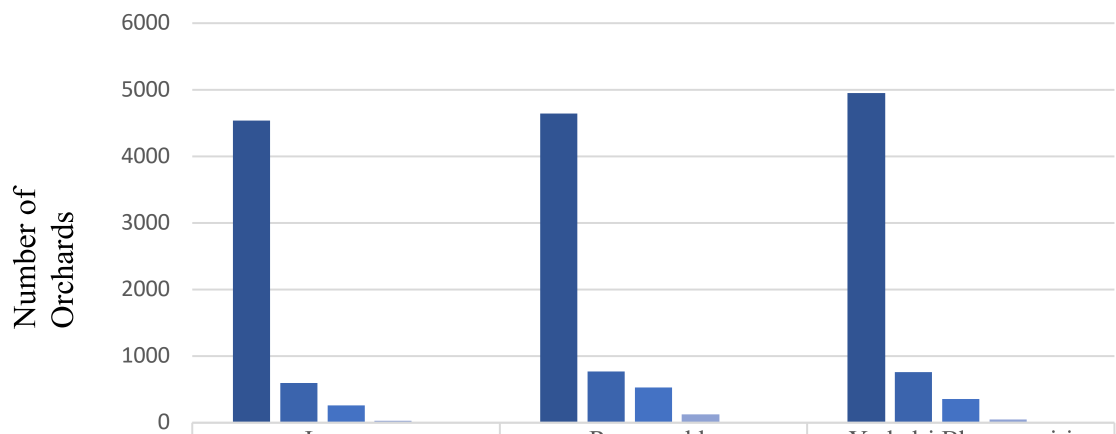


Figure 3 Classifications of Orchards Based on Orchard Size



	Jangaon	Rangareddy	Yadadri Bhuvanagiri
Marginal	4533	4640	4953
Small	598	772	763
Semi- Medium	259	527	361
Medium	30	125	51
Large	0	0	0

Figure 4 Size-Based Orchard Distribution in the Study Area

A farmer (who owns the mango orchard), hired managers (who work for the orchard owner), or pre-harvest contractors (who take a lease of the mango orchard from the farmer) manage mango orchards. According to the contract terms, pre-harvest contractors lease the orchard from farmers in the post-harvest season (undertake all of the operations for the following harvest season on their own). Else, acquire a lease of the orchard post-flowering season or during the early fruit set stage (R. Srihari Babu, 2015).

1.2 Mango Supply Chain

The mango supply chain encompasses the production, distribution, and consumption phases. The orchard operations phase of the mango consists of pre-harvest and harvest practices. During the pre-harvest and harvest season, farmers hired managers or pre-harvest contractors to perform all operations in the mango orchard with the support of extra laborers for harvesting operations. Farmers either sell their produce directly to a post-harvest buyer (who provides a lump sum amount and buys the entire yield) or take it to the nearest collection center (i.e., mandi). Several commission agents or wholesalers at the mandi conduct parallel open auctions and mediate between the farmer, pre-harvest contractor, and buyer (R. Srihari Babu, 2015). We have categorized the mango operations from orchard to mandi into pre-harvest practices, harvest practices, and post-harvest practices, as shown in Figure 5.

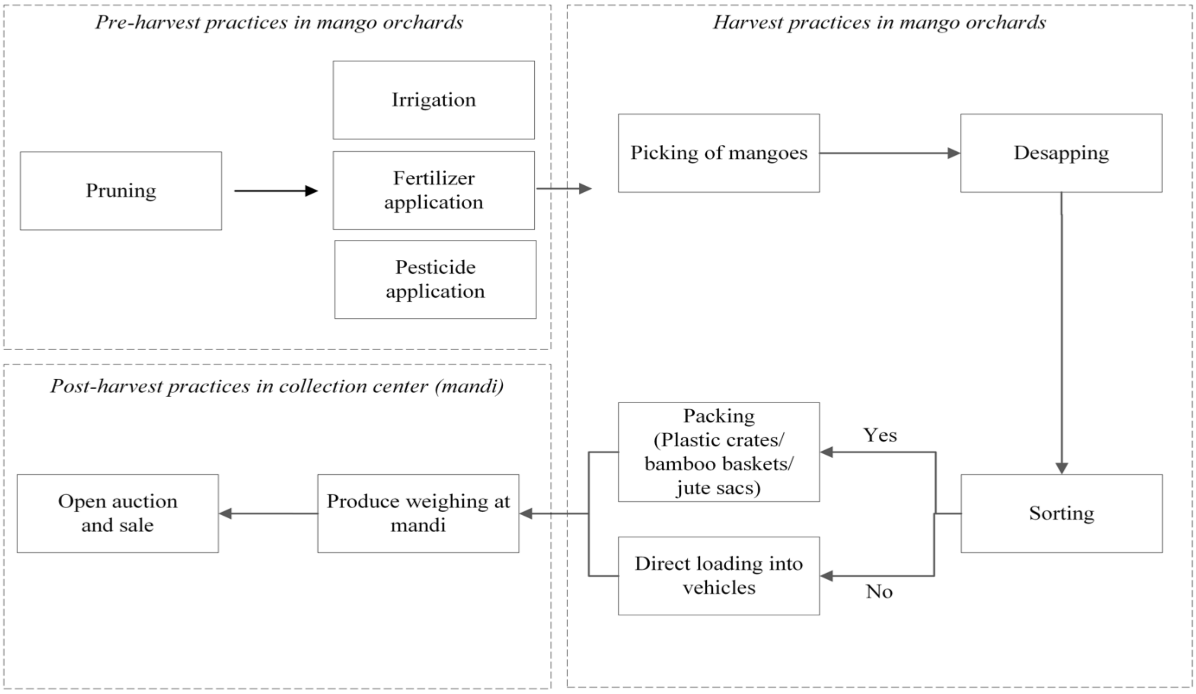


Figure 5 Mango Supply Chain, from Orchard to a Collection Center (Mandi)

Pre-harvest practices include pruning, irrigation, fertilizer application, and pesticide application (Figure 6). Pruning removes a section of a tree's branches to promote a more uniform branch distribution and enhanced airflow within the mango tree (Figure 7). Sunlight has beneficial effects on the development of mango fruit (S. P. Kumar et al., 2020). Irrigation practices vary greatly depending on the crop and soil type (Williamson and Crane, 2010). Mango trees are irrigated year-round, except during the rainy season, and the irrigation method differs from orchard to orchard (Figure 8). Applying fertilizers adds nutrients to the soil to increase yield; knowing the right fertilizer, using the fertilizer at the right time, and knowing the cost of fertilizer might impact losses (Azam *et al.*, 2022). During the flowering season of mango trees, pesticide use controls pests that may affect the fruit, the suitable pesticides, using the pesticides at the right time, and the cost of pesticides might impact losses (Muriithi *et al.*, 2021).

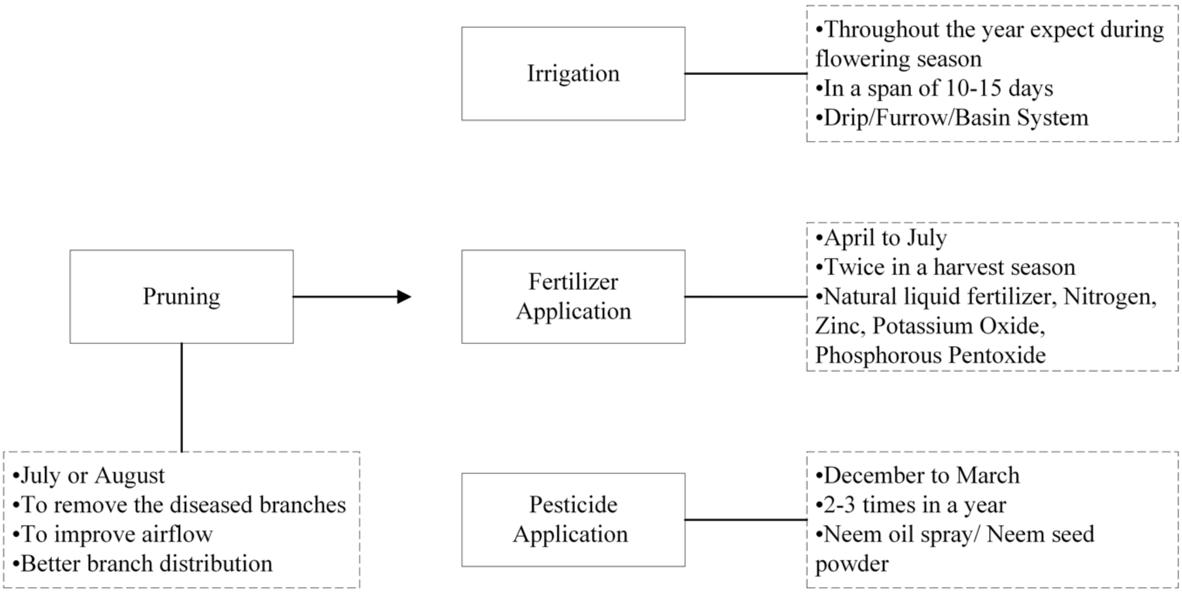


Figure 6 Pre-Harvest Practices in Mango Supply Chain

Figure 7 Mango Pruning

Figure 8 Mango Drip Irrigation System

Harvest practices include picking, desapping, and sorting (Figure 9). The harvesting process is the primary determinant of mango post-harvest management. Picking mangoes depends on their maturity, and the farmer decides to pick them during the early hours of the day to reduce the exposure of mangoes to sunlight after harvesting (Gómez-Lagos et al., 2021). Desapping removes the stalk attached to the fruit after harvesting (Figure 10). Desapping helps remove sap from the stalk, helping avoid sap burns (Barman et al., 2015). Farmers usually sort small, medium, and large-sized mangoes in plastic crates (Figure 11). Other forms of packing include bamboo baskets and jute sacks. Farmers load all the mangoes into the truck without sorting (Figure 12).

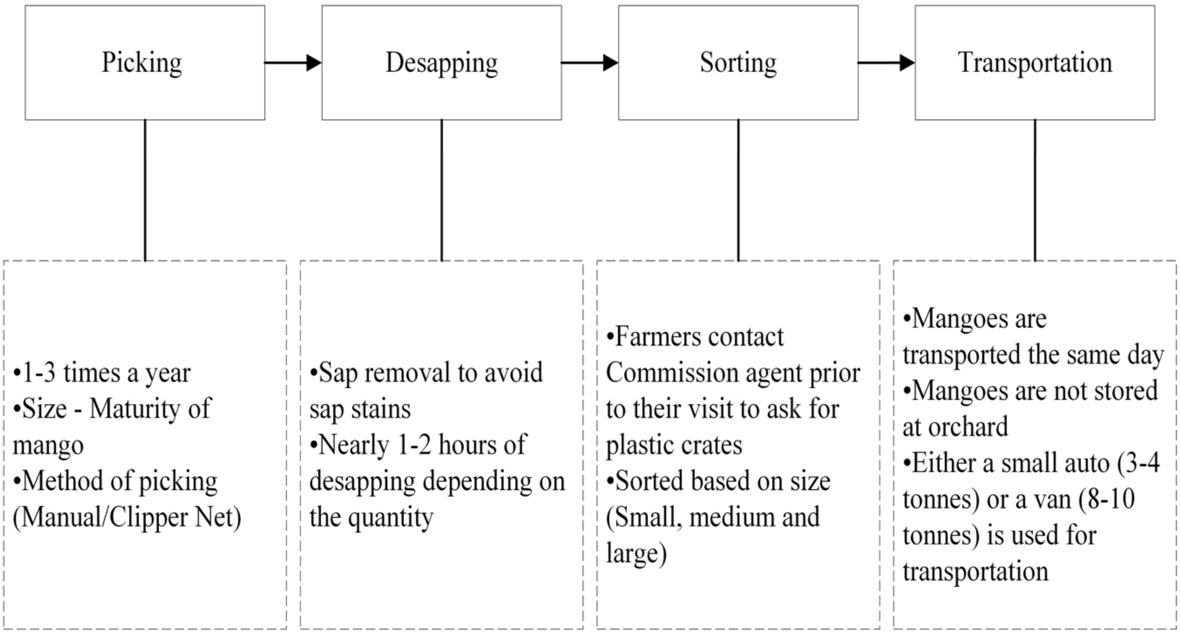


Figure 9 Harvest Practices in the Mango Supply Chain

Figure 10 Desapping Process

Figure 11 Mangoes Sorted Into Crates

Figure 12 Mangoes Without Sorting

Post-harvest practices include packing and transporting mangoes to the nearest mandi for sale (Figure 13). A commission agent or wholesaler mediates between the farmer and the buyer by selling the produce fairly through an open auction at the mandi (Figure 14) (R. Srihari Babu, 2015), storing mango in orchards, or utilizing cold storage. Farmers can access government-owned cold storage facilities for a nominal fee.

In the mango supply chain, losses could occur in different stages, in the pre-harvest, harvest, and post-harvest stages. The study focuses on pre-harvest and harvest losses in mango orchards. Our study excludes post-harvest stages because there have previously been studies on post-harvest losses, post-harvest handling, and mango shelf life extension.

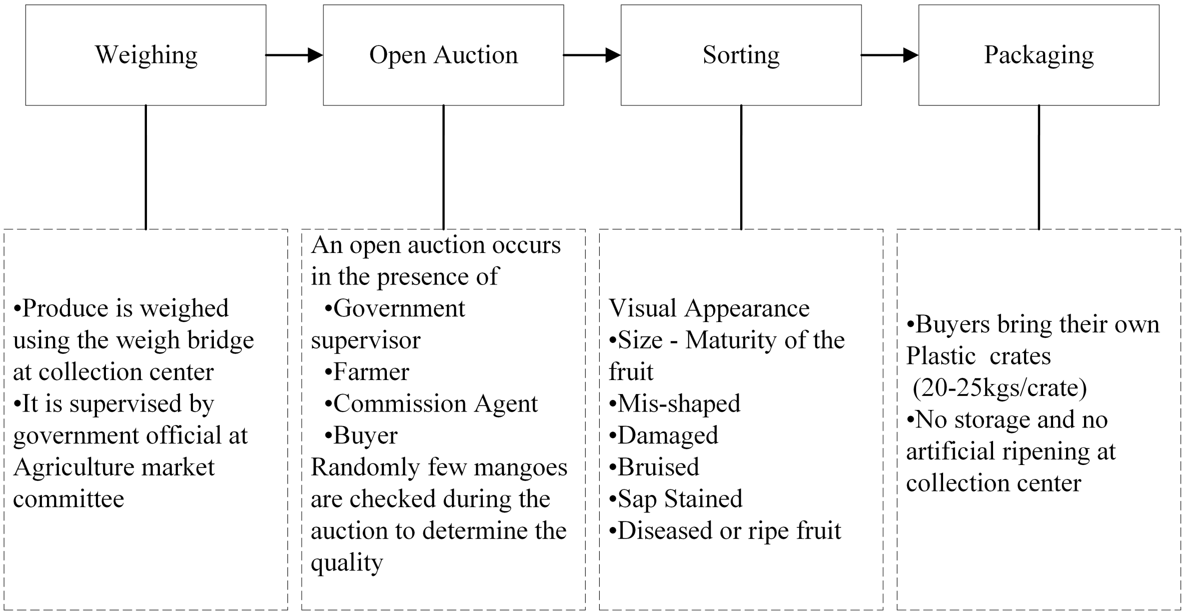


Figure 13 Post-Harvest Practices Till Mandi in Mango Supply Chain

Figure 14 Collection Center - Mandi

Pre-harvest losses account for all the losses in the yield from the fruit set stage to the pre-mature stage. The climatic conditions, the prevalence of pests and diseases, and the physiological stress placed on the trees can lead to both qualitative and quantitative losses during the pre-harvest stage (FAO, 2017). Losses at harvest include fruit loss due to over-ripeness and damaged fruit resulting from improper harvesting practices in which the fruit is dropped directly on the ground. Harvesting losses include qualitative losses when handling immature, irregular, or bruised fruit. Post-harvest losses occur due to lengthy transportation. 10 to 15 percent of the produce is lost due to post-harvest losses because there are no nearby local markets. Quantitative losses are due to rough handling and damaged rotten fruit.

1.3 Research Questions

i. What factors impact the pre-harvest losses in the mango supply chain?

ii. What factors impact the harvest losses in the mango supply chain?

iii. What factors impact the harvest quality of mangoes in the supply chain?

iv. What factors impact the harvest quantity of mangoes in the supply chain?

1.4 Research Objectives

i. To study the factors impacting pre-harvest losses in the mango supply chain and suggest recommendations to farmers.

ii. To study the factors impacting harvest losses in the mango supply chain and to suggest recommendations to farmers.

iii. To study the factors impacting the harvest quality (size of mango) of mangoes in the supply chain and suggest recommendations to farmers to enhance the harvest quality.

iv. To study the factors impacting the harvest quantity of mangoes in the supply chain and to suggest recommendations to farmers to increase the harvest quantity.

1.5 Scope of the Study

The study focuses on the orchard operations phase of the supply chain, i.e., in the mango supply chain, pre-harvest and harvest practices contribute to the orchard operations phase. This study aims to determine all the factors influencing the pre-harvest and harvest losses harvest quality and harvest quantity in the mango supply chain. This study develops four comprehensive frameworks to identify the factors.

Firstly, the study identifies the significant factors influencing mango supply chain losses during the pre-harvest and harvest stages. To comprehend the pre-harvest losses, we have compiled data on the percentage loss of fruits at the early and middle stages of fruit development, i.e., post-flowering fruit set stage to the pre-mature phase of fruit. To comprehend the harvest losses, we have gathered information on the percentage loss of fruits due to over-ripeness, i.e., a tree's fruit that has reached maturity but has yet to be harvested. Next, factors influencing the harvest quality and harvest quantity of mangoes were studied. This study utilizes the size of the mango, which is the proxy for harvest quality at the mandi for determining the market rate. Farmers-hired managers, or pre-harvest contractors, are the respondents. The respondents for the study represent three districts of Telangana, namely Jangaon, Rangareddy, and Yadadri Bhuvanagiri.

1.6 Motivation for the Study

Mango is the largest produced fruit in India. Numerous studies on the horticultural aspects of mango orchards emphasize various pre-harvest and harvest practices. However, understanding the significance of variations in these operations based on orchard types is critical. Most farmers in developing nations such as India are marginal and small; focusing on informing these farmers about the distinctions could allow them to make more revenue. Over 92% of the overall population in the study area consists of marginal (80%) or small (12%) sized orchards. The motivation for this study was to assist in educating marginal-sized farmers about the significant orchard operations they are currently employing and how to reduce orchard losses and improve the harvest quality and harvest quantity of mangoes. Also, there exists a gap in the literature on the aspects of the operational management of mango orchards. Understanding orchard operations that influence pre-harvest and harvest losses, harvest quality, and harvest quantity are necessary as it ultimately helps farmers receive a higher market rate.

1.7 Outline of Thesis

Chapter 1: Introduction

This chapter overviews the study's background, describes the mango supply chain, outlines its objectives and research questions, and defines its scope and motivation. This chapter also contains the chapter-by-chapter outline of the thesis.

Chapter 2: Literature Review

This literature review examines the full scope of activities carried out in mango orchards until mandi between harvests. This section covers pre-harvest practices, harvest practices, and mango orchard losses. An examination of the relevant literature from an operational, horticultural, and economic standpoint is performed to get a better perspective.

Chapter 3: Research Methodology

This chapter describes the research methodology used to address the study's objectives. It represents the research design, sampling, and an explanation of the techniques used in this study.

Chapter 4: Factors Influencing Pre-harvest Losses in Mango Supply Chain

This chapter presents the results of the factors influencing pre-harvest losses. This chapter addresses the first and fourth research objectives.

Chapter 5: Factors Influencing Harvest Losses in Mango Supply Chain

This chapter presents the results of the factors influencing harvest losses. This chapter addresses the first and fourth research objectives.

Chapter 6: Factors Influencing the Harvest Quality of Mango Supply Chain

This chapter provides an overview of factors impacting the harvest quality of mangoes in orchards. Results from this chapter help in addressing the second and fifth research objectives.

Chapter 7: Factors Influencing Harvest Quantity in Mango Supply Chain

This chapter provides an overview of factors impacting the harvest quantity of mangoes in orchards. Results from this chapter help in addressing the third and fifth research objectives.

Chapter 8: Conclusion and Future Research Directions

This chapter summarises the study's findings. The section concludes with a discussion of the significant limitations of this study, along with suggestions for future research focusing on mango orchard operations.

1.8 Conclusion

This chapter provided an introduction to this doctoral research work. First, the background of this study was described, followed by the mango orchard operation. The chapter then outlined the study's research questions and relevant research objectives. This was followed by an explanation of the study's scope and motivation. Lastly, the chapter concludes with an outline of this thesis work. The next chapter includes a comprehensive literature review upon which this doctoral work was planned and executed.

2 CHAPTER: LITERATURE REVIEW

This chapter is structured as follows: first section discusses the review methodology, which provides a detailed description of selected publications for the current study—followed by descriptive literature analysis, consisting of the distribution of research publications based on the timeline, publication type, geography, and bibliometric analysis. The last section presents a critical analysis covering the significant aspects of the mango supply chain and provides gaps in the existing literature (Figure 15).

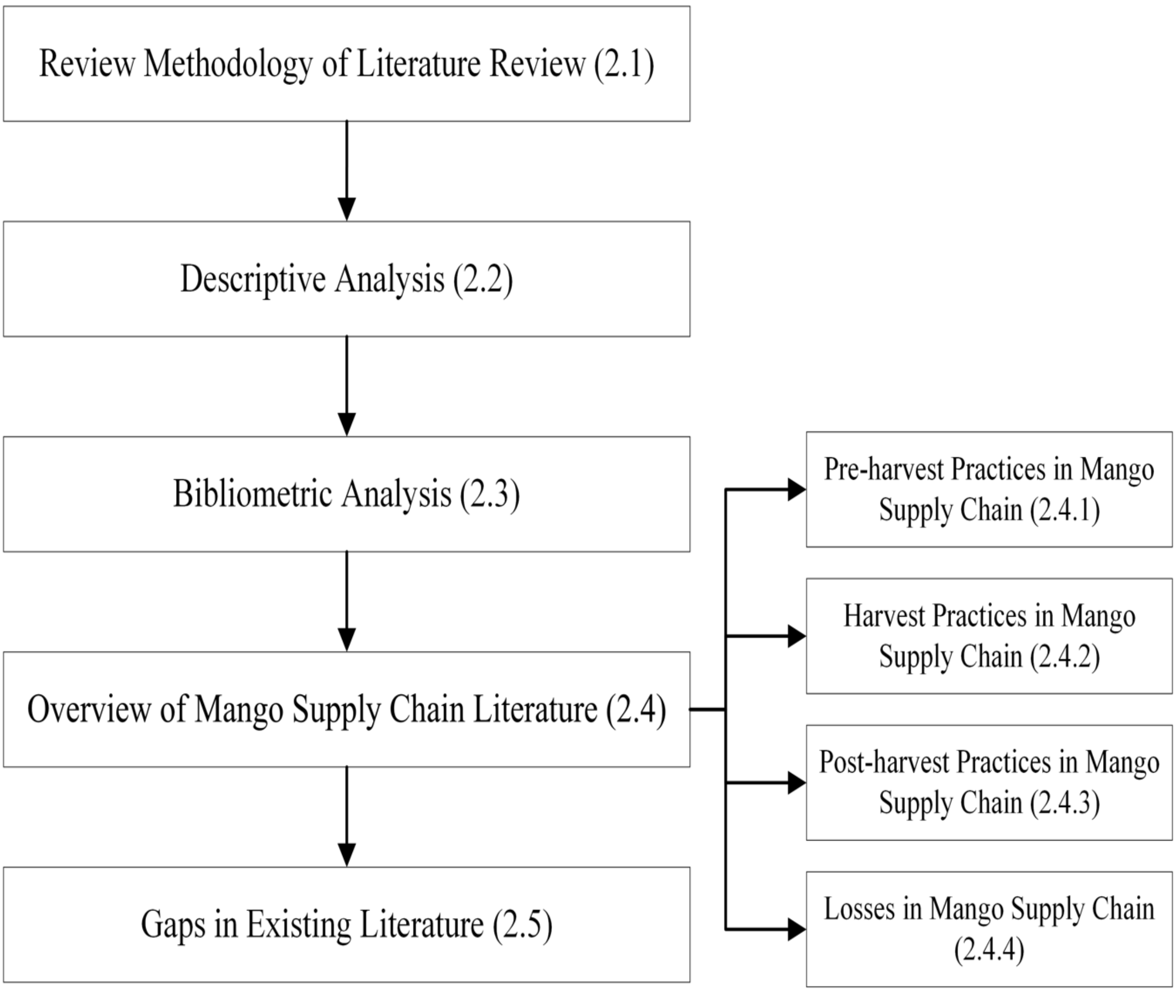


Figure 15 Overview of Chapter 2

2.1 Review Methodology

A comprehensive evaluation of research publications from 2000 to 2022 was conducted. The sources of research publications for the study are from the Scopus, Web of Science, and Google Scholar databases; it includes publications from peer-reviewed journals, conference proceedings, and books. Research publications were identified using a systematic search of keywords, such as "mango supply chain," "mango," "horticulture supply chain," "fresh produce supply chain," "fruit supply chain," pre-harvest practices," and "harvest practices." A total of 160 publications resulted from the initial search. Bibliometric details of all these papers were created in Microsoft Excel. Through abstract assessment, irrelevant publications were removed, resulting in 119 publications (Figure 16).

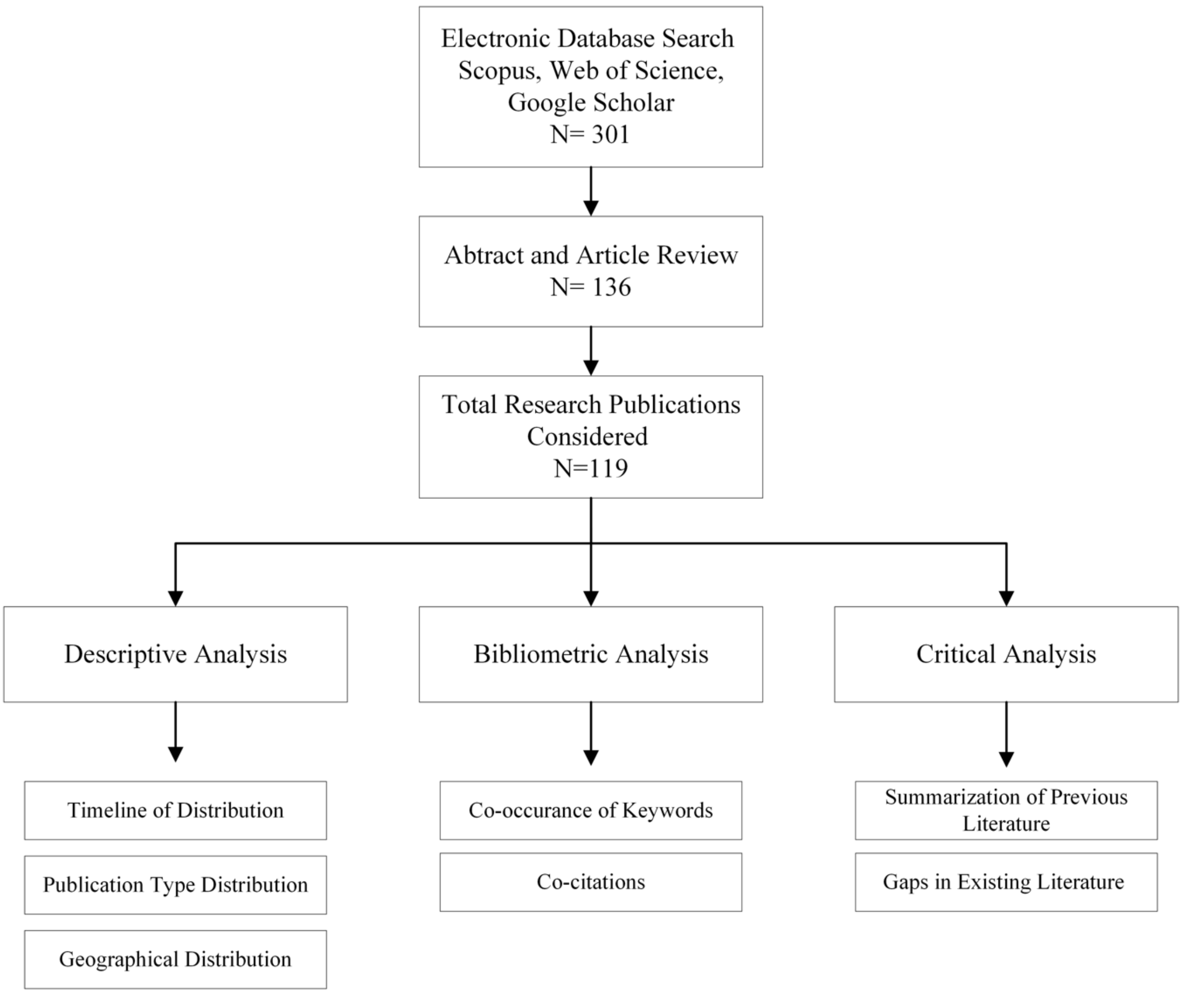


Figure 16 Review Methodology of Literature

2.2 Descriptive Analysis

This analysis aims to identify the current status of the mango supply chain and the essential and most researched themes. Firstly, the frequency of the papers published is determined to understand the growth of research over a while. In addition, the distribution of publications over different countries is analyzed to comprehend the research type being performed. Furthermore, a bibliometric analysis was performed to identify the significant themes of the mango supply chain using co-occurrence network analysis of keywords and citations.

2.2.1 Timeline of Distribution of Publications

This distribution represents the frequency of all 119 research publications from 2000 to 2022. Figure 17 shows that the number of researchers in the mango supply chain is increasing continuously. This analysis revealed that nearly 67 percent (80) of the research publication are from only the last ten years.

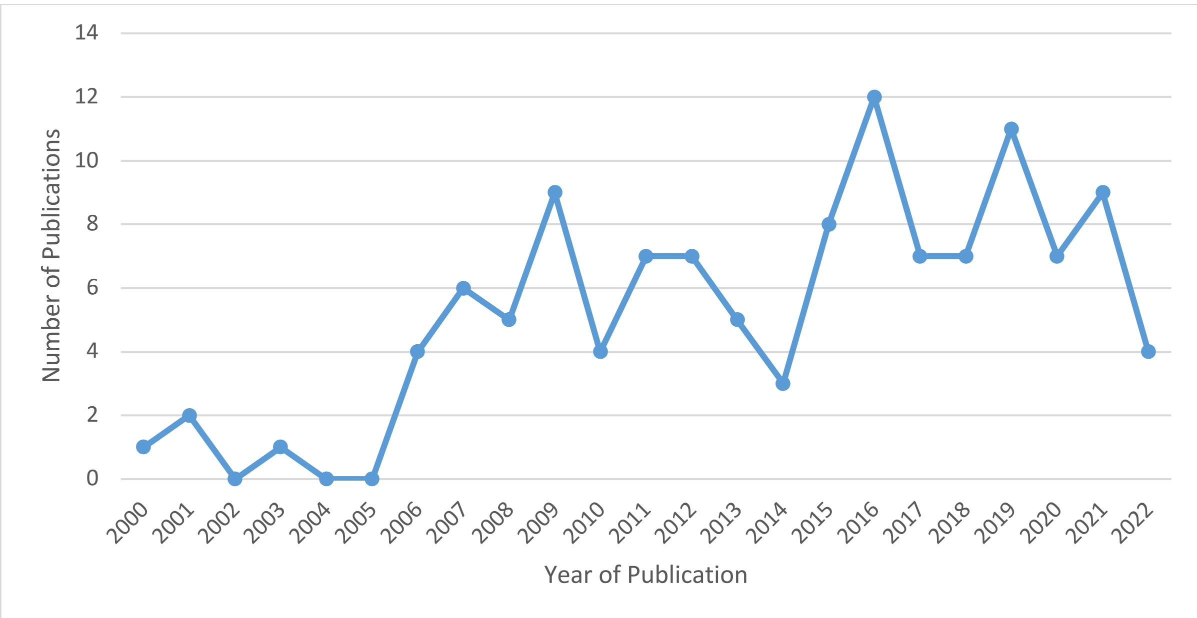


Figure 17 Timeline Distribution of Publications

2.2.2 Publication-Type Distribution

The study analyzed 119 publications, with 67 research articles, 40 book series, nine books, and three conference proceedings. Sixty-seven articles were amongst reputed journals such as "The

International Journal of Production Economics," "International Journal of Operations and Production Management," "Journal of Cleaner Production," "Journal of Agricultural Economics," "Agricultural Economics (United Kingdom)," "Agronomy," "Agricultural and Resource Economics Review," and "Resources, Conservation, and Recycling." Figure 18 presents the distribution of publications based on their type.

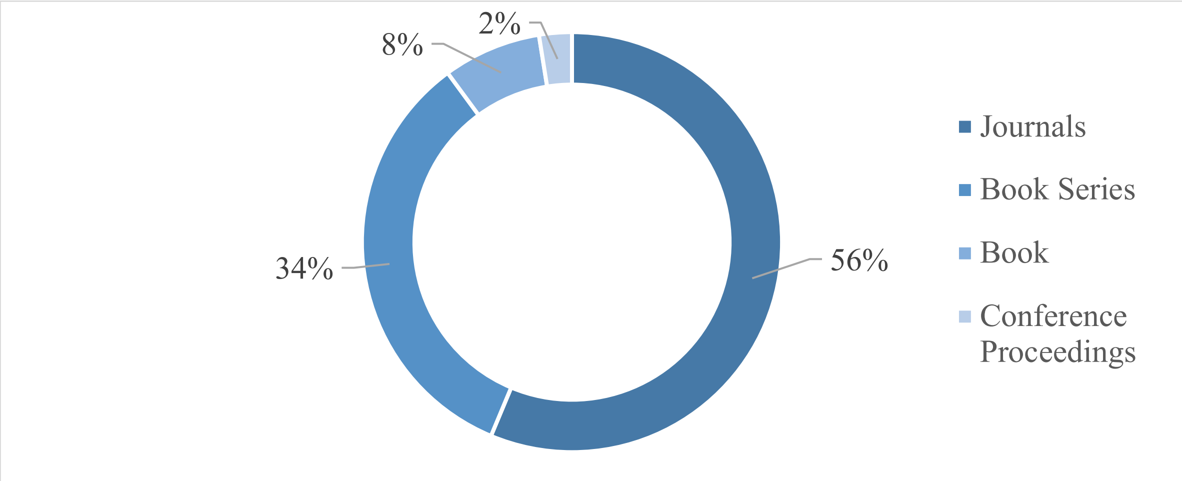


Figure 18 Distribution Based on Publication-Type

2.2.3 Geographical Distribution of Publications

As shown in Figure 19, research publications are distributed across developing and developed countries. The highest number of publications collected are from India, followed by Australia.

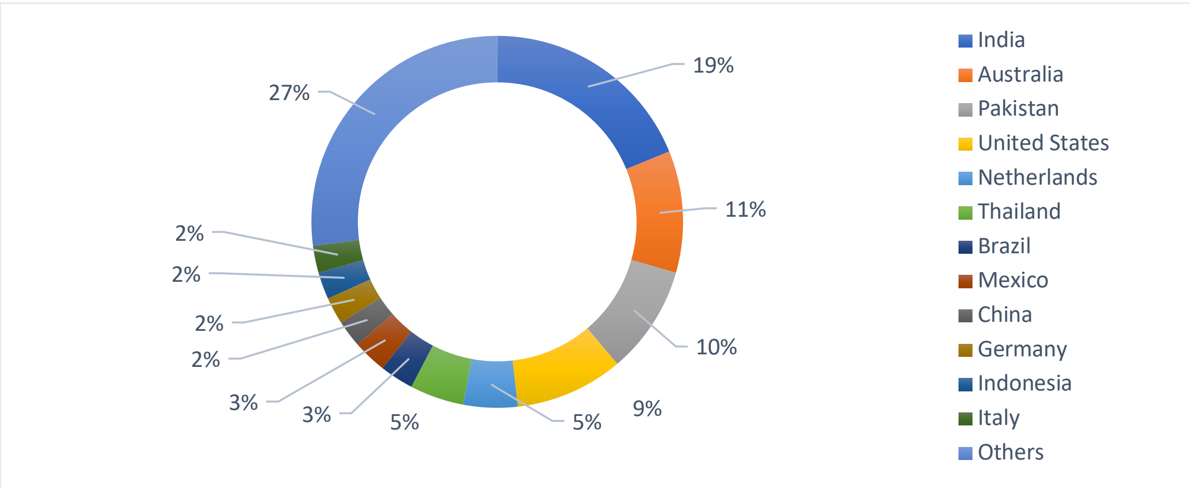


Figure 19 Geographical Distribution of Publications

Table 1 represents the distribution of research publications in all the countries for a detailed comprehension of Indian research publications mainly focused on the post-harvest mango supply chain.

2.3 Bibliometric Analysis

The purpose of this analysis is to identify the essential themes in the area of the mango supply chain. A co-occurrence network analysis of keywords and co-citation is performed using VOS viewer software. An association-based normalization algorithm was used for the clustering and mapping of keywords. A total of 540 keywords were identified from all the research publications. The software requires a minimum number of keywords that occur together in a publication. The threshold was set to 2 keywords that occur together for analysis. The number of keywords that resulted from the set threshold was 69 (Figure 20). The highest occurred keywords are mango and supply chain management. The co-citation network is presented in Figure 21.

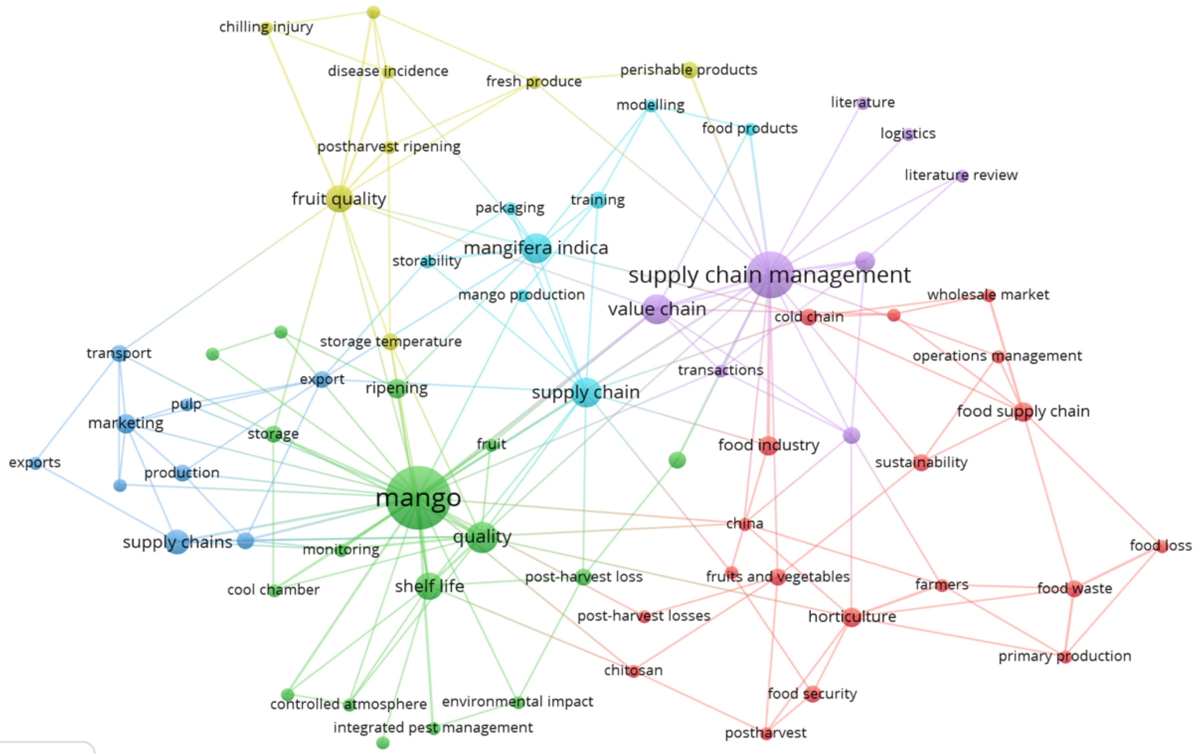


Figure 20 Co-occurrence Network of Keywords

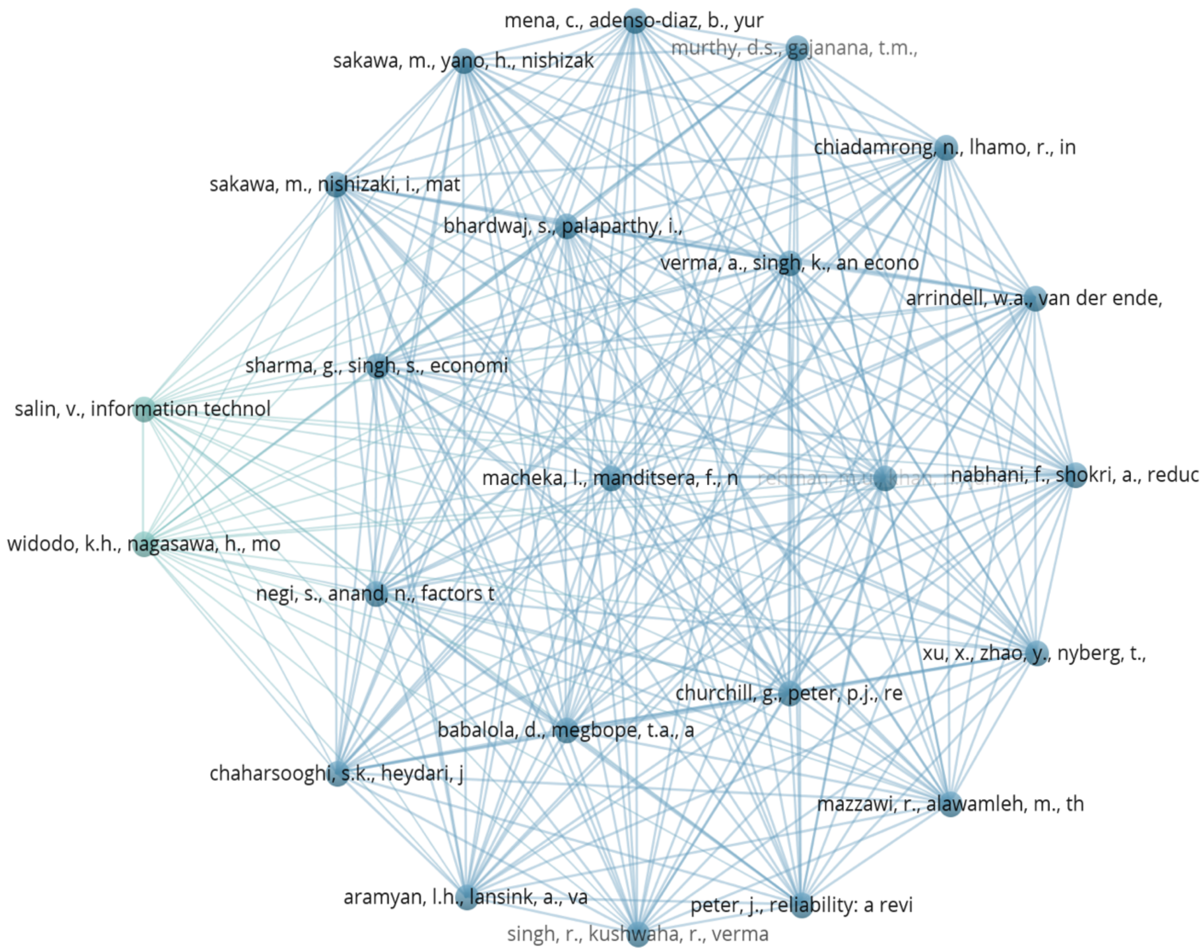


Figure 21 Co-Citation Network

2.4 Literature Overview of Mango Supply Chain

The mango supply chain consists of the production, packing, transportation, and distribution of mangoes to different markets. The orchard operations phase of the supply chain includes cultivation, pre-harvest practices (pruning, fertilizer application, pesticide application), and harvesting (picking, desapping, sorting) (Alam, 2018). After harvesting, all the practices are termed post-harvest (Ravindra and Goswami, 2007a). Table 1 presents the literature on the mango supply chain classified into pre-harvest, harvest, and post-harvest phases.

Table 1 Distribution of Publication in the Mango Supply Chain

Authors	Year	Pre-harvest	Harvest	Post-harvest
Shafique et al.	2022			✓
Dhaigude, Mukherjee and Kaushik	2022			✓
Tarekegn and Kelem	2022			✓
Tavassoli-Kafrani et al.	2022			✓
Ma and Sexton	2021	✓	✓	✓
Baptista et al.	2021	✓	✓	
Dutta, Deshpande, and Rai	2021			✓
Belasco and Schahczenski	2021	✓		
Widi, Sari and Jahroh	2021			✓
Gianguzzi et al.	2021		✓	
Herrera and Orjuela-Castro	2021			✓
Din et al.	2021			✓
Mitra	2020	✓	✓	✓
Hor et al.	2020	✓		
Baltazari et al.	2020			✓
Gabriëls et al.	2020			✓
Bundi et al.	2020	✓		
Pereira, Scarpin and Neto	2020			✓
Krishnan et al.	2020			✓
Oberoi and Dinesh	2019	✓	✓	✓
Gnanavel et al.	2019			✓
Kehoe et al.	2019			✓
Anderson et al.	2019			✓
Midingoyi et al.	2019	✓		
Ren et al.	2019	✓		
Negi and Anand	2019			✓
Ntsoane et al.	2019			✓
Phuangto et al.	2019			✓
Negi and Wood	2019			✓
Monira, Aziz and Mondal	2019			✓
Wang et al.	2018	✓		
Johnson et al.	2018		✓	
Rahman et al.	2018			✓
Ambuko et al.	2018			✓

Authors	Year	Pre-harvest	Harvest	Post-harvest
Alam	2018		✓	✓
Yasunaga et al.	2018			✓
Kasso and Bekele	2018			✓
Mehdi et al.	2017			✓
Siddiq, Brecht and Sidhu	2017		✓	✓
Brecht and Yahia	2017		✓	✓
Evans, Ballen, and Siddiq	2017		✓	✓
(Arinloye *et al.*, 2017)	2017	✓	✓	✓
Orjuela-Castro, Diaz Gamez and Bernal Celemín	2017			✓
Panjun and Sachakamol	2017			✓
Pardhi et al.	2016			✓
Shwetha and Naik	2016			✓
A.U. Malik, Amin and Asad	2016		✓	✓
Mehdi et al.	2016			✓
Mutonyi et al.	2016			✓
Taiti et al.	2016			✓
Fiaz et al.	2016		✓	✓
Barboza, Mamede and Brito	2016			✓
Giannetti et al.	2016		✓	✓
A U Malik, Amin and Asad	2016			✓
Vanany et al.	2016			✓
Prevez et al.	2016			✓
Karyani et al.	2016			✓
Yasunaga et al.	2016			✓
Kumari and Bairwa	2015			✓
Obour et al.	2015	✓		
Matulaprungsan, Boonyaritthongchai, Wongs-Aree, S. S. Kanlayanarat, et al.	2015			✓
Matulaprungsan, Boonyaritthongchai, Wongs-Aree, S. Kanlayanarat, et al.	2015	✓		✓
Cardoen et al.	2015			✓
Singh and Zaharah	2015			✓
Mohithkumar et al.	2015			✓
R. Srihari Babu	2015			
Natawidjaja et al.	2014			✓

Authors	Year	Pre-harvest	Harvest	Post-harvest
Gupta and Jain	2014			✓
Singh, Singh, and Yadav	2014		✓	✓
Aguinaldo et al.	2013		✓	✓
Yuniarti and Santoso	2013			✓
Johnson et al.	2013			✓
Esguerra and Bautista	2013			✓
Siddiq, Akhtar, and Siddiq	2012			✓
Narayana, Rao, and Roy	2012		✓	✓
Baloch and Bibi	2012		✓	
de Castro Souza and Neto	2012			✓
Kitinoja and AlHassan	2012			✓
Watanawan et al.	2012			✓
Hafeez, Malik and Rehman	2012			✓
Meijer, Ruben and Hofstede	2011			✓
Ahumada and Villalobos	2011		✓	✓
Kienzle et al.	2011		✓	
Sivakumar, Jiang and Yahia	2011			✓
Goel	2011		✓	✓
Collins	2011			✓
Collins and Iqbal	2011			✓
Malik et al.	2010			✓
Mazhar et al.	2010			✓
Patil	2010			✓
Ullah et al.	2010			✓
Naidua and Naidu	2009			✓
Kapsea, Pawar, and Sakhaleb	2009			✓
Murthy et al.	2009			✓
Yahia	2009			✓
Campbell	2009		✓	✓
Gunjate	2009	✓		
Jannoyer et al.	2009		✓	✓
Sakhale, Pawar and Kapse	2009			✓
Zúñiga-Arias, Ruben and van Boekel	2009			✓
Sudha and Kruijssen	2008			✓
Fizzanty, Collins, and Russell	2008			✓

Authors	Year	Pre-harvest	Harvest	Post-harvest
Prokopy et al.	2008	✓	✓	
Mitra	2008		✓	✓
Anwar and Malik	2008			✓
Zúñiga-Arias and Ruben	2007			✓
Zúñiga-Arias et al.	2007			✓
Ravindra and Goswami	2007			✓
Diedhiou et al.	2007			✓
Neidhart et al.	2007			✓
Montalvo et al.	2007			✓
Qin et al.	2006			✓
Ledger et al.	2006		✓	✓
Hofman and Ledger	2006			✓
Jha, Kingsly and Chopra	2006		✓	✓
Dhemre and Waskar	2003			✓
Fallik et al.	2001			✓
Van Mele, Van Huis and Thu Cuc	2001	✓		
Acosta et al.	2000			✓

2.4.1 Pre-Harvest Practices in Mango Supply Chain

Pruning removes a portion of a tree's branches to produce more uniform branch distribution and improve ventilation within the mango tree. S. P. Kumar et al. (2020) experimented on 'Kent's mango orchards; two pruning processes were conducted for experimentation. One technique opens the canopy to expose as much fruit to sunlight as possible, while the other produces square-shaped trees and reduces the amount of sunlight reaching the fruit. This study provided evidence for the beneficial effects of sunlight on red color development without harming the harvest quality of the mango fruit.

Irrigation practices vary greatly depending on the crop, soil type, and management philosophy (Williamson and Crane, 2010). Irrigation techniques implemented in a mango orchard include the basin, furrow, drip, or sprinkler. Schulze et al. (2013) conducted a study that deployed micro sprinklers in two commercial mango orchards, which utilized full irrigation based on climatic water balance, deficit irrigation, and farmer-controlled scheduling. Results showed that deficit irrigation significantly boosts crop water productivity and stabilizes yield during drought. Whereas with full irrigation and micro-sprinkler usage, farmers' profit can be raised by 55%. Few similar studies conducted as a means of conserving irrigation water by Liu et al. (2021), Lipan et al. (2021), and Spreer et al. (2009) used four irrigation levels, full irrigation throughout the growth period, and regulated deficit irrigation during flowering, fruit expansion, and maturity. Full irrigation met all the crop's water requirements. Regulated deficit irrigation levels received reduced water levels with 75%, 50%, and 33% of irrigation water, respectively. Results showed that regulated deficit irrigation decreased mango size without impacting mango production. Regulated deficit irrigation at maturity increased fruit output by 10.1% in 2018 and improved average weight. Irrigation timing also affects mango yield (Zhang et al., 2019). In 2018–2019, an orthogonal mango drip fertigation experiment examined how irrigation volume and fertilizer regime affected mango harvest quantity, fruit harvest quality, water usage efficiency, and partial fertilizer productivity. Sun et al. (2022) conducted an orthogonal experiment on mango under drip fertigation to explore the effects of irrigation volume and fertilizer regime on mango yield, fruit quality, water use efficiency, and partial fertilizer productivity. The four parameters were irrigation amount and fertilization rate at the flowering, fruit expansion, and fruit ripening growth stages. The results showed that the optimal water and fertilizer scheduling for high yield, quality, and water-fertilizer usage efficiency was irrigation with 75% and fertilization with 50, 75, and 25 kg ha 1 at the flowering, fruit expansion, and fruit ripening stages, respectively.

Fertilizer usage influences crop productivity and fruit quality. Azam et al. (2022) examined the effects of nitrogen (N), phosphorus (P), and potassium (K) fertilizers on mango orchard vegetative and reproductive development, yield, and fruit quality. NPK increased mango trees' fruiting, yield, physiochemical characteristics, and fruit quality. After treating mango trees with phosphorus, De Mello Prado (2010) analyzed their nutrition and growth. Using fertilizer increased phosphorus levels in the soil but only altered plant performance in the second year. Phosphorus increased the diameter of the plant's stem after three years of treatment but did not affect the fruit set.

Pesticide application is vital since farmers' predicted production loss due to insect pests is directly proportional to pest severity. In Vietnam's Mekong Delta, researchers in Van Mele, van Huis, and Thu Cuc (2001) examined farmers' knowledge, perceptions, and practices regarding mango pest management. All farmers sprayed insecticides (97%) and fungicides (79%) from pre-flowering until harvest, averaging 13.4 and 11.6 applications per year. Farmers' projected yield loss due to insect pests was substantially associated with estimated pest severity. The spray load of farmers increased from 26 to 37 sprays per year because of suggestions from pesticide dealers. In contrast, the number of insecticide products used per farmer increased from 2.6 to 3.9 because of recommendations from extension personnel.

Over 47% of 820 rice, sugarcane, bean, eggplant, potato, cabbage, and farmers in Bangladesh utilized excessive levels of pesticide, according to a report. Pesticide misuse significantly impacts misunderstanding, income, farm ownership, chemical toxicity, crop mixture, and geography (Dasgupta, Meisner, and Huq, 2007).

S. kifouly G. Midingoyi et al. (2019) assessed the effects of integrated pest management (IPM) strategies on mango yield, net income, insecticide use, human health, and the environment using household survey data from Kenyan mango growers. Using a multinomial endogenous switching treatment regression model. The findings showed that IPM-adopting farmers have higher mango yields and net income, use less insecticide, and cause less harm to the environment and human health. Moreover, transitioning from a single IPM approach to many IPM practices produces more significant economic, environmental, and human health benefits. Examined in Ethiopia were the knowledge, beliefs, and actions of small farmers regarding mango pests, as well as their intention to employ IPM technology as a sustainable technique for mango fruit fly management. The fruit fly was the research region's most economically significant mango pest. Fruit flies contributed to 28% of mango output declines (Muriithi *et al.*, 2021).

Wang et al. (2018) emphasized sustainable agriculture development in developing nations. Farmers' choice of organic fertilizers over chemical fertilizers is positively influenced by participation in agriculture cooperatives, subsidies on organic fertilizers, and farm size.

Sarker, Rahim, and Archbold (2016) investigated combinations of fertilizer rates and irrigation methods to enhance mango growth, flowering, and yield. Two treatment combinations derived from several years of prior studies of individual practices were compared: one combination was comprised of the best individual practices from the prior studies and included three applications of fertilizer, and both combinations significantly advanced the dates of flowering and harvest, increased panicle number, length, and secondary branching, increased fruit set, fruit number at harvest, fruit size, and yield. Even though both combinations yielded fruit of higher quality than the control

Using data from many sources and stakeholders, Kumar et al. (2016)) evaluated the performance of small rainwater harvesting structures (farm ponds) in five primary rainfed states of India from 2009 to 2011. Technical support, customized design, level of farmer participation, age, existing ownership of open wells, annual rainfall, and household assets were the primary determinants of the performance of farm-level rainwater harvesting structures, according to a functional analysis of the reasons for widespread adoption of water harvesting structures. Based on this nationwide investigation, various policy and institutional approaches are recommended for boosting farm-level rainwater gathering for dryland agriculture.

Peralta-Antonio et al. (2014) investigated the soil nutrient content, trunk diameter, blooming, and yield of three mango cultivars: 'Manila,' 'Tommy Atkins,' and 'Ataulfo' in response to mineral and organic: vermicompost, bokashi, and chicken manure fertilizers. Chicken manure was discovered to be comparable to nitrogen doses on soil concentrations of nitrogen, phosphorus, copper, and zinc; fertilizer does not affect trunk diameter.

2.4.2 Harvest Practices in Mango Supply Chain

Mango picking involves plucking the fruit off the trees, which requires a brief period of intense work (Gómez-Lagos et al., 2021). According to Gianguzzi et al. (2021), the length of the harvesting season depends on the number of days after complete flowering. To evaluate the progression of cv's most essential physicochemical and organoleptic characteristics. Osteen fruits refer to their length of time on the plant and their post-harvest care. A one-way ANOVA determined that mango fruits on the tree attain the highest quality characteristics, corresponding to their physiological maturity. The length of storage required to reach the point of consumption varies widely based on the time of harvest and the many environmental factors which also affect the organoleptic and physicochemical quality of the fruits. It was determined that the number of days after full flowering is the most crucial factor to consider when planning harvest for commercial use of the fruit; however, exciting indications can be obtained through the definition of non-destructive (hardness, color) or destructive (dry matter) parameters. Harvesting between 126 and 133 days after full bloom was optimal for customer acceptance.

Chen and Chen (2021) used a stochastic programming model to examine the options of picking during a harvesting season to minimize the predicted cost given workforce, storage space, shelf life, and transportation constraints. We employ the sample-average approximation to provide a high-quality stochastic program solution. Mango harvesting requires more labor in June than in July and August because naturally matured mangoes are harvested in June, and this cannot be altered. Therefore, it is recommended to plant additional mango types to alleviate workforce shortages during harvest season. Because they are sold shortly after harvest, organically ripened mangoes require less storage space. In order to maximize operational flexibility, more significant storage space should be prepared to keep mangoes artificially matured.

A study by Escallón-Barrios et al. (2022) offered an end-to-end analytics method consisting of data treatment, descriptive (simulation), and prescriptive (optimization) models to improve harvest activities in this agricultural system. The models comprised strategic (harvest cycle), tactical (resource distribution), and operational decisions (transport allocation). In addition, they have created operational solutions that reduce the average harvest cycle time from 19.6 to 8.3 days.

Zhang et al. (2019) used boundary line analysis based on survey data from 103 smallholder farmers, and a yield gap model was used to determine the yield gap and production constraints in mango plantations in the northern mountain, central valley, and southern mountains regions of Tianyang County, Guangxi, China. Mango yields in three representative regions of Tianyang County, Northern Mountains, Central Valley, and Southern Mountains, were 18.3, 17.0, and 15.4 t ha–1 yr–1, with an explainable yield disparity of 10.9, 6.1, and 14.8 t ha–1 yr–1, respectively. Fertilization management, including N, P2O5, K2O treatment rates, and planting density, were the primary yield-limiting factors in all three zones. In addition, mango yield in the Northern Mountains (11.1%) and Central Valley (11.7%) was affected by tree age, and in the Northern Mountains (9.9%) and Southern Mountains (12.0%), irrigation time affected mango yields. Based on a scenario study, the expected yield would grow by up to 50 percent, while N fertilizer use would decrease by up to 20 percent.

Mangoes are desapped after picking. Mangoes are de-stemmed; sap pours from the stem create sap burn on the mango's outer layer, diminishing the fruit's quality. Barman et al. (2015)

investigated desapping on the Chausa type of mango; fruits were de-stemmed and immediately treated with multiple desapping chemical solutions. The fruits were air-dried and kept at room temperature (30±2 °C) for 12 days after treatment. Compared to the other treatments, fruits with sodium hydroxide (1%) exhibited much-reduced sap burn injury. This treatment enhanced the fruit's shelf life by reducing ripening through reduced respiration and ethylene evolution rates.

Jonkman et al. (2019) offered an overview of agro-food industrial networks' supply chain design problem, considering seasonality, harvesting decisions, perishability, and processing. The findings indicate that a supply chain design model customized to an agro-food supply chain's specific characteristics and uncertainties leads to identifying supply network configurations with superior performance.

Barman et al. (2015) studied the effect of several putative desapping agents on the decrease of sap burn injury and their effects on mango fruit quality during storage under ambient conditions. Shortly after harvest, fruits were de-stemmed and dipped for 5 minutes in several desapping agent solutions [calcium hydroxide (1%), sodium hydroxide (1%), alum (0.5 and 1%)]. In control fruits, the pedicels were eliminated, and the surface sap was permitted to flow freely. After applying the treatment, the fruits were air-dried and stored at room temperature (30 ± 2 °C) for 12 days. The sodium hydroxide (1%) and alum (0.5%) treatments resulted in much less sap burn injury than the control treatment.

Cobourn et al. (2013) analyzed a scenario in which the pest control decisions of growers collectively result in a shift in pricing that minimizes the losses from infestation for some farms while harming others. Producers with superior fruit vary harvest schedules the most, profiting from the consequent change in the quality premium at the expense of growers of inferior fruit. More significant fruit is more susceptible to harm by the olive fruit fly, but they also command a premium on the market. The tension between these conflicting effects and their respective strength determines the ideal harvest date for a specific producer. Ahumada and Villalobos, (2011) proposed an operational model for the fresh produce business that generates short-term planning decisions. The results also indicate that dynamic, information-based management approaches may be preferable to traditional practices based on fixed labor allocation and distribution.

Widodo et al. (2006) developed a fundamental model of fresh agricultural products by mathematically representing fresh products' plant growth and loss processes. The model addresses periodic harvests through periodic flowering in order to meet demand. A periodical flowering–harvesting problem was formulated to maximize the demand level satisfied in each period. The optimal solution was derived analytically, assuming that on-hand inventory cannot be carried through more than one period and any requirement for harvesting fresh products should be satisfied as soon as possible.

2.4.3 Post-Harvest Practices in Mango Supply Chain

Javed et al. (2022) compared the effects of pre-and post-storage quarantine heat treatments, hot water treatment, and vapor heat treatment on the post-harvest performance of 'Chenab Gold' mango fruit. After 21 days of cold storage, the application of hot water at 48ºC for 60 minutes or vapor heat at 47 ºC for 25 minutes increased ethylene production and fruit weight loss while lowering fruit firmness and vitamin C content.

Negi and Anand (2018) investigated the reasons and most significant variables leading to supply chain inefficiency at the wholesale level of the tomato supply chain in India in terms of high cost, considerable lead time, and poor quality. From factor analysis, four factors for high cost were identified: labor charges, operational, resources, and infrastructure; five factors for a high lead time were identified: operational, labor, resources, and infrastructure; and five factors for poor quality were identified: operational, infrastructure, ambiance, labor, and information. The data indicate that labor costs and operational issues are the most significant contributors to inefficient supply chain management.

Shukla and Jharkharia (2013) presented a literature assessment on the supply chain management for fresh vegetables. The fresh produce supply chain management encompasses operations from production to consumption (fruits, flowers, and vegetables). The key finding of this analysis is that consumer satisfaction and income maximization are the primary goals, while post-harvest waste reduction is a secondary target. The review reveals that most material is fragmented and organized in silos. Lack of demand forecasting, the mismatch between demand and supply, and a less-integrated strategy are the primary causes of the issue.

2.4.4 Losses in Supply Chain

According to Lu et al. (2022), food loss has been recognized as a significant obstacle to food security and environmental sustainability in developing nations. A large-scale field study was conducted using the questionnaire survey and qualitative interviews of 1809 farmer families in 35 key agricultural-producing counties of 12 provinces throughout China between April 2017 and September 2019. This study demonstrates a substantial opportunity to reduce food loss along the food supply chain, which accounts for more than 40 percent of the current normalized food loss rate for essential agrifood items. Important mitigation techniques suggested include educating farmers about contemporary harvesting and post-harvest technology, boosting the usage of the cold chain, and creating knowledge on nutrition and health among consumers to avoid.

Beausang, Hall, and Toma (2017) investigated farmers' perspectives on food waste and losses in soft fruit and vegetable fields. The study demonstrated, through thematic analysis, that farmers do not view food waste as a significant worry but as an inherent aspect of agriculture. Farmers have trouble giving estimates of food waste and losses because they do not frequently document waste. Several reasons for food waste highlighted in this study are attributable to problems higher upstream in the food supply chain, such as store aesthetic requirements and a lack of processing capabilities. This study revealed that farmers do not consider food waste a severe concern but a natural agriculture component. Due to infrequent waste recording, it is difficult for farmers to provide estimates of food waste and losses.

Magalhães, Ferreira, and Silva (2021) found causes for fruit and vegetable supply chain losses. The Matrix Effect of Cross Multiplication and Adapted Interpretive Structural Modelling were utilized to identify five root causes. Inadequate transportation systems, inadequate or defective packaging, lack of storage facilities, poor handling and operational performance, and lack of coordination and information sharing are the causes to reduce food loss and waste.

Gardas, Raut, and Narkhede (2018) found the most critical factors that must address to ensure a progressive reduction in post-harvest losses in India's fruit and vegetable supply chain. Factors are lack of proper packaging and storage facilities, lack of adequate infrastructure, better handling of the products on the farm and in the market, lack of processing facilities, lack of links between farmers and processing units, lack of links in the marketing chain, and many intermediaries. They have utilized DEMATEL and MCDM analysis techniques. The results revealed that the most important factors that should be addressed to ensure progressive post-harvest loss reduction are: inadequate packaging facilities, inadequate storage facilities, inadequate infrastructure, improved handling of the products at the farm and marketplace, inadequate processing facilities, insufficient linkage between farmers and processing units, insufficient linkage in the marketing channel, and a large number of intermediaries.

De Gorter et al. (2021) provided a first principles-based economic model of food waste for consumers, intermediaries, and farmers. It is differentiated between purchases and sales for every intermediary, purchases and consumption for consumers, and gross output and sales for farmers. At each point of the food supply chain where the rate of food waste lowers, the amount of food waste decreases. Due to the existence of waste, producers, and intermediaries, such as processors and retailers, must charge a higher price per unit sold to recoup the costs incurred on all units, including the wasted units. Hence, reducing waste rates always increases sales at lower prices for each producer and intermediary. It is resulting in increased sales and, thus, more waste at all other supply chain stages. Generally, total food supply waste continues to diminish.

Johnson et al. (2018) proposed a simple method for field-level assessment and demonstrated its applicability on six vegetable crops gathered from 13 fields on a 121-hectare farm in North Carolina. Through a case study methodology, the study's findings revealed that, on average, around 65 percent of the unharvested produce that remained in the field was of healthy, edible quality, even though its appearance may not have met the aesthetic requirements of purchasers in some marketplaces. The case study farm had an estimated average of 8,840 kg per hectare of healthy, unharvested vegetable crops that were recoverable. The average percentage of a grower's total marketable produce that remained unutilized in the field was 57%, which far exceeds current estimates of farm-level loss. Finding solutions to exploit these losses could enable growers to enhance the quantity of fresh produce flowing through the supply chain and is a step towards the sustainable intensification of vegetable crop production.

Despoudi et al. (2018) studied the impact of different types of collaboration on post-harvest food losses and the proportion of low-quality peaches produced using a unique data set of Greek peach producers. According to regression analysis, high levels of cooperation between producers and cooperatives are associated with minimal post-harvest food losses and a low proportion of low-quality peaches. Furthermore, we discover that some types of collaboration, such as "goal congruence," can substantially impact minimizing post-harvest food losses and enhancing the quality of peach output at the distribution's extremities. This study identifies significant policy implications for collaborative methods and systems that can reduce post-harvest food losses and enhance a producer's performance and sustainability credentials.

Redlingshöfer et al. (2017) investigated the amount of food loss and waste at the upstream stages of food supply chains in industrialized nations; how it may be quantified at these levels; and the role that reuses and recycling play in the reduction of food loss and waste. Four plant sectors (cereals, pulses, oil crops, and fruit/vegetables/potatoes) and six animal sectors (milk, beef, lamb, pig, poultry, eggs, and farmed fish) were evaluated. The findings imply that food loss occurs in the upstream stages of supply chains. The roles of the various supply chain phases vary among food sectors. Based on the findings of our 2013 study, between 3 and 11% of food was wasted from production to processing, and up to 12% for fruit, vegetables, and potatoes (up to retailing in the case of fruit and vegetables). Recycling, directly or indirectly reusing rejected food as food or animal feed, significantly reduces food waste during primary production and processing.

Balaji and Arshinder (2016) identified the sources of food waste and their driving force and interdependence and analyzed their relationships. With the application of fuzzy MICMAC and comprehensive interpretive structural modeling, it has been determined that the absence of scientific harvesting techniques and the vast number of intermediaries in the supply chain have a solid driving force and can be considered the fundamental causes of food loss. This work categorizes the causes into many tiers, allowing for the identification of the most pressing cause.

Fehr and Rom˜ao (2001) detected losses of fruit and vegetables in the various post-harvest stages of their life cycle, conditions of handling, transportation, and commercial distribution during these stages, as well as the reasons for identified losses and proposed solutions. In a city of medium size in Brazil, the total weight of fruit and vegetable waste throughout the marketing phase was 16.6%. It accounted for 3.4% of complete home waste at the consumer level. Specific reasons for this waste were discovered at the producer, wholesaler, and retailer levels. Short-term solutions were suggested, which typically rectified inadequate management methods. It has been demonstrated that relatively straightforward administrative actions can considerably reduce the rotting of fruits and vegetables.

2.5 Gaps in Existing Literature Review

India accounts for nearly 45 percent of the world's mango production; however, research on the following areas of the mango supply chain in the Indian context is minimal. Studies have focused on increasing the shelf-life of mangoes for export purposes. However, more studies on expanding the harvest quantity of mangoes at the orchard level are essential as they will improve the supply of mangoes across the globe. Many studies have focused on post-harvest losses; however, reducing the losses at the orchard operations phase of the supply chain is necessary to improve the harvest quantity and farmer's income. Studying pre-harvest and harvest losses of the supply chain is essential in this context. Studies have been performed on the quality of mango during the post-harvest phase of the supply chain. At the same time, the quality of mangoes viewed at the wholesale market (mandi) is the size of the mango. Studies must be performed on improving mango harvest quality in the supply chain's orchard operations phase. Further studies on various orchard types are needed to increase awareness of marginal and small farmers. The problem of sustainable practices throughout the mango supply chain requires examination and studies on yield management in mangoes and other fruits and the technological applications of mango.

3 CHAPTER: RESEARCH METHODOLOGY

This chapter outlines the method utilized to address the study's research objectives. The chapter is divided into three sections (Figure 22). Initially, factors extracted from literature research and expert interviews are presented. Following the study's research design description is a discussion of the sampling techniques utilized to collect the study's data. Afterward, provide an overview of the research techniques used to fulfill the stated objectives of this study.

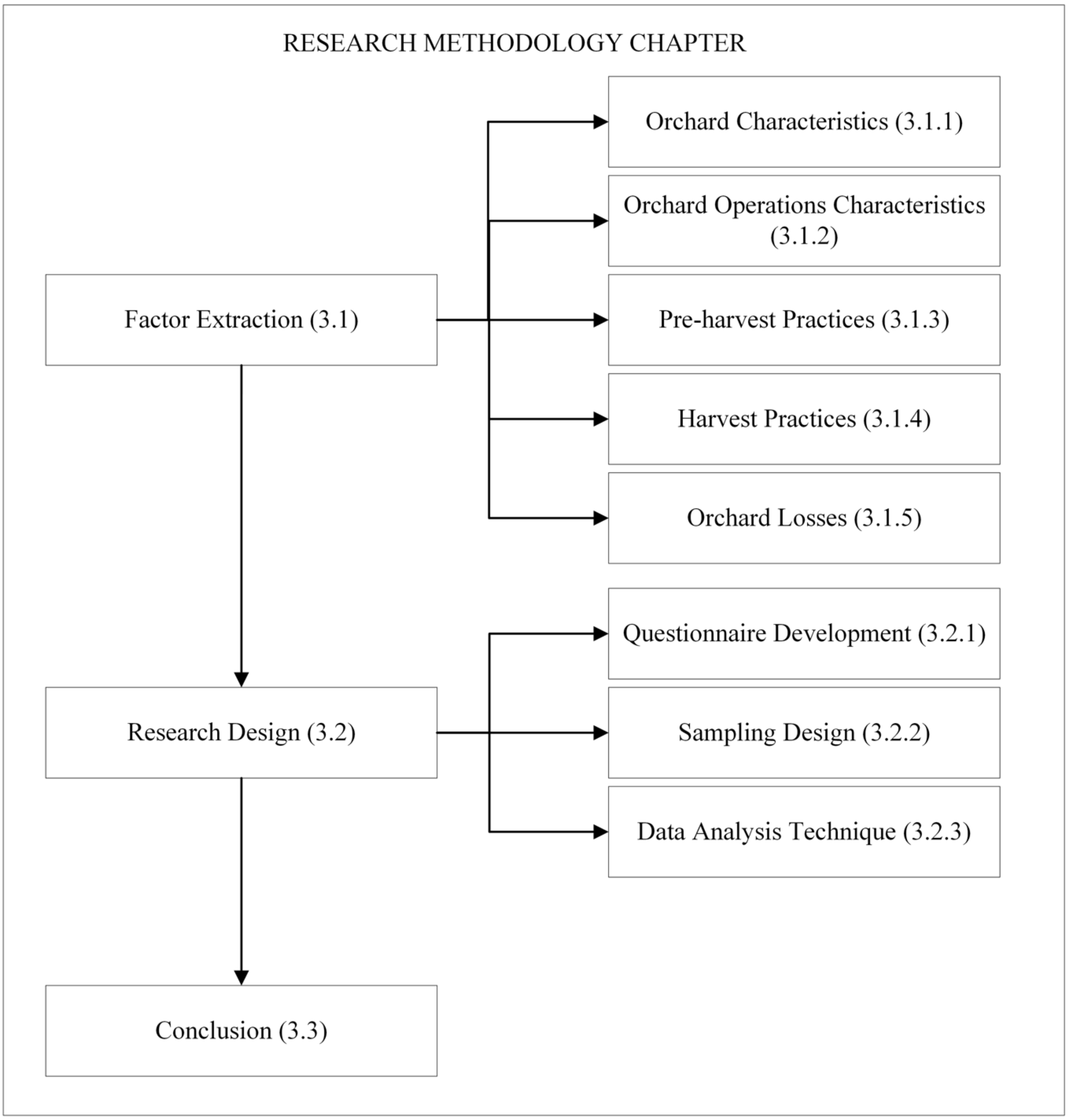


Figure 22 Overview of Chapter 3

3.1 Factors Extraction

Literature review and discussions with experts, including district horticulture officials and farmers, gave us factors for the study. We contacted 25 farmers and three horticulture officials from all three districts to begin the questionnaire development process. To get the experts' take on how the mango orchard operates, we structured some open-ended questions for them to answer. In addition, sub-sections 3.1.1–3.1.5 thoroughly describe the 20 factors used in this study.

3.1.1 Factors Determining Orchard Characteristics

Five factors represented orchard characteristics; orchard type – based on size, variety of mango, the weighted average age of trees, count of trees, and district. Table 2 shows the description of each of these factors. The Government of India's Ministry of Agriculture and Farmer's Welfare classifies Indian orchards into five categories based on the size of the orchard: marginal, small, semi-medium, medium, and large (Ministry of Agriculture & Farmers Welfare, 2019). We evaluated the orchard area, and only four classifications exist in these three districts: marginal, small, semi-medium, and medium. It was determined through consultation with experts that the mango tree's yield increases with age. If properly cared for, older trees may produce significantly more mangoes. Equation 1 presents The calculation of the weighted average age of trees.

$$\text{The weighted average age of trees} = \frac{\text{The average age of tree} * \text{Total count of trees of each age group}}{\text{Total count of trees}} \quad (1)$$

Table 2 Factors Determining Orchard Characteristics

Factor Extracted	Factor Operationalized		Reference
	Factor Type	Description	
Orchard type	Categorical - Binary	This factor determines whether the orchard type; marginal or small, or semi-medium. (For analysis: not marginal= 0 and marginal =1) (For analysis: not small= 0 and small =1) (For analysis: not semi-medium =0 and semi-medium =1) (We dropped medium orchard type) (Appendix – A: Question 13)	(Ministry of Agriculture & Farmers Welfare, 2019)
Variety of mango	Numeric - Discrete	This factor determines whether the orchard has a few or wide mango varieties. (For analysis: 1 [a proxy for a few] to 7 [a proxy for wide varieties]) (Appendix – A: Question 14)	(APEDA, 2021)
The weighted average age of the tree	Numeric - Continuous	This factor represents the weighted average age of trees in a mango orchard (Refer to equation 1 for calculation)	Field survey
Count of trees	Numeric - Discrete	The total number of trees in a mango orchard determines this factor (Appendix – A: Question 15)	Field survey
District	Categorical -Binary	Factor represents the district where the mango orchard is present (For analysis: not Jangaon = 0 and Jangaon=1) (For analysis: not Rangareddy= 0 and Rangareddy =1) (Appendix – A: Question 11)	Field survey

3.1.2 Factors Determining Orchard Operations Characteristics

We extracted two factors indicating orchard operations characteristics through discussions with experts: experience in orchard operations and orchard management. We learned from farmers that farmers or hired managers manage orchard operations. Table 3 presents the operationalization of these factors for this study.

Table 3 Factors Determining Orchard Operations Characteristics

Factor Extracted	Factor Operationalized		Reference
	Factor Type	Description	
Experience in orchard operations	Numeric - Continuous	Experience in years of performing or managing the mango orchards (Appendix – A: Question 7)	Field survey
Orchard management	Categorical -Binary	Information regarding the person responsible for managing the mango orchard (For analysis: hired manager = 0 and farmer =1) (Appendix – A: Question 12)	Field survey

3.1.3 Factors Determining Pre-Harvest Practices

Factors representing pre-harvest practices include pruning, irrigation method, variety of fertilizer, fertilizer application frequency, cost of fertilizer, variety of pesticide, pesticide application frequency, and cost of pesticide. Table 4 presents the description of these factors for this study.

Table 4 Factors Determining Pre-Harvest Practices

Factor Extracted	Factor Operationalized		Reference
	Factor Type	Description	
Pruning	Categorical -Binary	Performing pruning after the harvest season (For analysis: pruning not performed= 0 and pruning performed =1) (Appendix – A: Question 43)	(S. P. Kumar et al., 2020)
Irrigation method	Numeric - Discrete	Mango orchards adapt various irrigation methods such as basin, furrow, drip, and sprinklers. This factor determines the	(González et al., 2004; Spreer et al., 2009; Huh & Lall, 2013;

		total number of irrigation methods used in orchards. (For analysis: 1 [a proxy for few] to 4 [a proxy for many]) (Appendix – A: Question 53)	Schulze et al., 2013; Sarker et al., 2016; Lipan et al., 2021; Liu et al., 2021; Sun et al., 2022)
Variety of fertilizer	Numeric - Discrete	Mango orchards use a range of fertilizers. This factor determines the total number of fertilizers used in orchards. (For analysis: 1 [a proxy for few] to 6 [a proxy for many]) (Appendix – A: Question 45)	(Gajalakshmi & Abbasi, 2004; Sarker et al., 2016)
Fertilizer application frequency	Numeric - Discrete	This factor determines, in a year, the frequency of fertilizer application (For analysis: 1 [a proxy for few] to 12 [a proxy for many]) (Appendix – A: Question 46)	(Wang et al., 2018; Sun et al., 2022)
Cost of fertilizer	Numeric - Continuous	The sum of costs of all the fertilizers used in a mango orchard for this study (Appendix – A: Question 47)	Field survey
Variety of pesticide	Numeric - Discrete	This factor determines the total number of pesticides used in orchards (For analysis: 1 [a proxy for few] to 6 [a proxy for many]) (Appendix – A: Question 49)	(van Mele et al., 2001; Gajalakshmi and Abbasi, 2004; Dasgupta et al., 2007)
Pesticide application frequency	Numeric - Discrete	This factor determines that in a year, the frequency of pesticide application. (For analysis: 1 [a proxy for few] to 12 [a proxy for many]) (Appendix – A: Question 50)	(Cobourn et al., 2013; Midingoyi et al., 2019; Muriithi et al., 2021)
Cost of pesticide	Numeric - Continuous	The sum of costs of all the pesticides used in a mango orchard for this study (Appendix – A: Question 51)	Field survey

3.1.4 Factors Determining Harvest Practices

Factors extracted for the harvesting season of mangoes (March to July) are the number of picking cycles, desapping, and sorting. Table 5 presents the description of each of these factors.

Table 5 Factors Determining Harvest Practices

Factor Extracted	Factor Operationalized		Reference
	Factor Type	Description	
Number of picking cycles	Numeric-Discrete	Represents the frequency of picking in a mango orchard in a harvesting season. Picking cycles ranging from 1 to 3 in a harvest season. (Appendix – A: Question 58)	(Gómez-Lagos et al., 2021; Escallón-Barrios et al., 2022)
Desapping	Categorical-Binary	Performing stalk removal for the harvested produce (For analysis: desapping not performed= 0 and desapping performed =1) (Appendix – A: Question 43)	(Barman *et al.*, 2015)
Sorting	Categorical-Binary	They are sorting the harvested produce into two categories based on size; small and medium and large mangoes. (For analysis: sorting not performed= 0 and sorting performed =1) (Appendix – A: Question 43)	Field survey

3.1.5 Factors Determining Losses in Mango Orchards

Factors representing losses in mango orchards are pre-harvest loss and harvest loss. Table 6 presents the description of these factors for this study.

Table 6 Factors Determining Losses in Mango Orchards

Factor Extracted	Factor Operationalized		Reference
	Factor Type	Description	
Pre-harvest loss	Numeric - Continuous	The percentage of loss faced by the respondents during the fruit-set and early maturity phases. (Appendix – A: Question 56)	(FAO, 2017)
Harvest loss	Numeric - Continuous	The percentage of loss faced by the respondents during the mature phase due to over-ripeness and mechanical damage. (Appendix – A: Question 57)	(FAO, 2017)

3.2 Research Design

There are numerous definitions of research design, Malhotra (2018) define it as a *framework or blueprint for conducting a marketing research study. It details the procedures necessary for obtaining the information needed to structure or solve marketing research problems.* The two main types of research designs are exploratory and empirical. This study employs an empirical research design. A structured questionnaire serves as the data collection instrument for the face-to-face survey.

3.2.1 Questionnaire Development

We created a structured questionnaire after conducting a thorough literature review and contacting farmers in mango orchards. The questionnaire comprises variables impacting the pre-harvest and harvest losses. We made the questionnaire in English and translated the completed version into the regional language (Telugu). We provided the questionnaire in both languages; farmers preferred to respond in the regional language. The first component of the questionnaire asked for the respondent's demographic information following details regarding the mango orchard. The final portion is about mango orchard pre-harvest and harvest practices. We presented our questionnaire using feedback from farmers and horticulture officers in the study area. After the pretesting, we improved the questionnaire and conducted a pilot study to determine the questionnaire's viability. The pilot study included 27 farmers from all three districts, and we made additional revisions to generate the final draft of the questionnaire. The final draft of the questionnaire had 65 questions, as shown in Appendix A and Appendix B, and it took approximately 30 minutes for respondents to complete.

3.2.2 Sampling Design

As depicted in Figure 23, the sampling design consists of five steps (Zikmund, 2013)***)***. The initial step of the sampling design process is identifying the target population. (Iacobucci and

Churchill, 2018) defined population as *the aggregate of all elements that share a predefined set of criteria and constitute the universe for research*.

Figure 23 Sampling Design

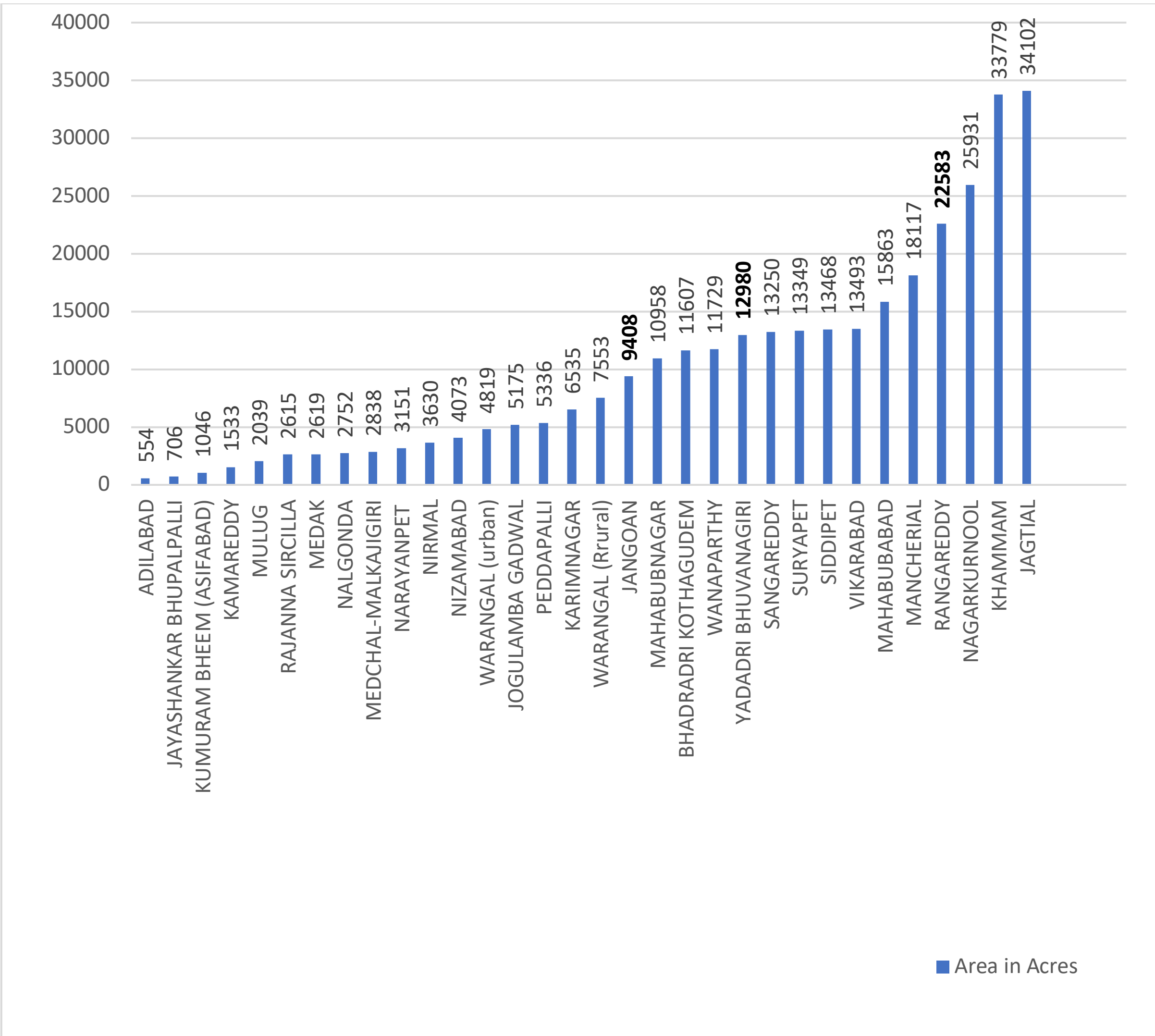


Figure 24 Area Wise Distribution of Mango in All the Districts of Telangana (2019-2020)

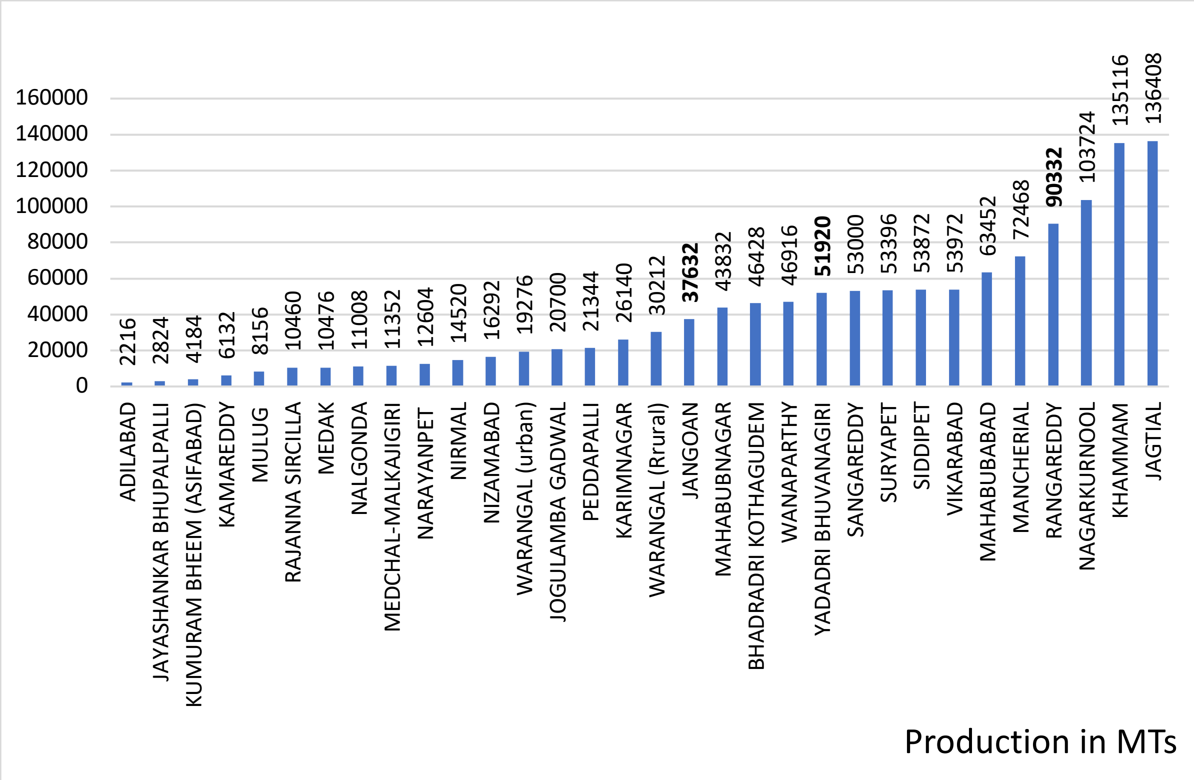


Figure 25 Production of Mango in All the Districts of Telangana (2019-2020)

The target population for the study includes mango-producing orchards. We studied in Telangana, India's Jangaon, Rangareddy, and Yadadri Bhuvanagiri districts. We purposively selected these districts as the majority of the mangoes grown are transported to one collection center (mandi), making it more accessible in comparison to the responses received. Figure 24 and Figure 25 present the distribution of mango orchards in acreage and harvest quantity of all the districts of Telangana. The sampling frame was the mango orchards in Telangana. We requested the sampling list from the district horticultural offices. Therefore, the mango orchard data were considered representative of this study.

Sample size and selection are critical for producing satisfactory data from questionnaire surveys. We used a stratified sampling technique for this study—each orchard's size represents one stratum. Collected responses are from all four strata, i.e., marginal, small, semi-medium, and medium. To establish sample size Roscoe (1975) provided a few rules of thumb, such as sample sizes between 30 and 500 are appropriate for most studies, and a minimum sample size of 30 is required for each subsample (males/females, juniors/seniors). We have applied the rule of thumb to establish the size. The calculation for the adequate sample size for the empirical study is based on Cochran's formula for large populations.

Cochran's formula: $n = \left(\frac{z}{e}\right)^2 p(1-p)$

Where –

n: sample size

Z: Confidence level (degree of uncertainty) considered 95%; therefore, z = 1.96.

e: The desired margin of error is the error that can be tolerated and considered as 5%.

p: The (estimated) proportion of the population. Here, 50 percent (0.5) is utilized to get the most significant variation.

$$n = \left(\frac{z}{e}\right)^2 p(1-p)$$

$$n = \left(\frac{1.96}{0.5}\right)^2 \text{ x } 0.5 \text{ x } (1-0.5)$$

$$n = (39.2)^2 \text{ x } 0.5 \text{ x } (1-0.5)$$

$$n = 1536.64 \text{ x } 0.5 \text{ x } 0.5$$

$$n = 384.16 \qquad n \cong 385$$

The margin of error and confidence level are essential criteria for calculating sample size (Cochran, 1977). Often, the confidence level is 0.05 or 0.01 (Ary, 2009). Using the table provided by (Barlett, 2001) confidence level of 95% and a margin of error of 5%, the sample size is computed to be 385.

Table 7 Sample Breakdown by Demographic Factors

	Number	*Percentage*
Gender		
Male	270	81.33
Female	62	18.67
Education		

Primary Schooling (1st-5th Standard)	17	5.12
Secondary Schooling (6th-10th Standard)	112	33.73
High School (11th and 12th Standard)	65	19.58
Under Graduation	81	24.40
Post-Graduation and above	28	8.43
Uneducated	29	8.73
Annual Income		
Less than 100000 INR	261	78.61
100000 to 200000 INR	38	11.45
Above 200000 INR	33	9.94

The study used a sample of 332, with nearly 110 respondents from each district, for the survey. We conducted a field survey by visiting mango orchards. We gathered data from the three districts through face-to-face interviews. Before data collection, we observed that farmers, hired managers, and pre-harvest contractors managed the orchards and were among our respondents. Face-to-face interviews were conducted from February to May 2022. Table 7 presents the demographic factors of the sample.

3.2.3 Data Analysis Techniques

The data was entered into an Excel sheet for analysis using an appropriate and consistent coding method to prevent errors. Multiple regression is a statistical approach that effectively investigates the relationship between numerous independent variables and a single dependent variable. Its primary use is in the study of correlations between these relationships. The study utilizing multiple regression has one primary goal: to use the independent variables, the already known values, to predict the outcome of the single dependent variable. Every predictor value is given a weight, with the weights indicating each predictor value's proportionate contribution to the total forecast. The regression results serve as the foundation for the design of the experimental model.

Design of experiments (DOE) is a methodical strategy for understanding how different process and product factors influence response variables and interaction effects (D.C. Montgomery, 2013a). Its objective is to investigate the main effects of factors and the interaction effects on the response factor. This facilitates a more holistic comprehension of how the various factors contribute to the ultimate result. The utilization of a full factorial design is implemented in the DOE in this study. Full factorial design means that all possible combinations of the factors are included in the experiments. This methodology guarantees the consideration of each factor's levels and interactions. It is a technique that makes the task easier, like any other tool, equipment, or method. DOE is a mathematical tool instead of a quality, mechanical, or process tool. Its purpose is to define the importance of particular product variables and processing and how to control them to maximize system performance while optimizing its properties. DOE uses statistical methods to assess data and anticipate product properties and performance under all potential scenarios while staying within the constraints established for the study design. In addition to gaining knowledge of how a single variable influences the performance of a product, it is also possible to identify the interactions between several process and product factors. DOE is a method or process that is used to generate the necessary information with the least amount of actual experimenting possible using the following: experimental limits, specific experimental conditions, mathematical analysis to predict the response at any point within the experimental limits.

The design of experiments-assisted parameter design optimization is utilized extensively in empirical work due to its reliability and effectiveness (D.C. Montgomery, 2013).

We have considered the 20 factors in the conceptual model through a literature review and expert discussions. However, the acquired data revealed that we had to exclude ten factors due to low inter-respondent variability. We analyzed the data on ten factors, including a variety of mango, age, count of trees, experience in orchard operations, orchard management, variety of fertilizers, cost of fertilizer, variety of pesticides, pesticide application frequency, and the number of picking cycles.

3.3 Conclusion

This chapter described in depth the research methods utilized in this study. This chapter briefly explains each of the methodologies used to achieve the specified research objectives and information about the sampling design of respondents. The analysis and results for our objectives are presented in the following four chapters (Chapters 4, 5, 6, and 7). We are illustrating our investigation's complete analysis and subsequent conclusions into determining the factors influencing pre-harvest losses, harvest losses, harvest quality, and harvest quantity in mango orchards.

4 CHAPTER: FACTORS INFLUENCING PRE-HARVEST LOSSES IN THE MANGO SUPPLY CHAIN

This chapter overviews the factors influencing pre-harvest losses in the mango supply chain. The chapter is divided into six sections. The first section provides an introduction to this chapter. Next, a literature review on pre-harvest practices is presented. The research methodology for this study is provided in the following section. Following that, the study's results are provided using multiple regression and the design of experiments. Finally, managerial implications and concluding remarks in this chapter are presented. Figure 26 depicts a visual overview of this chapter.

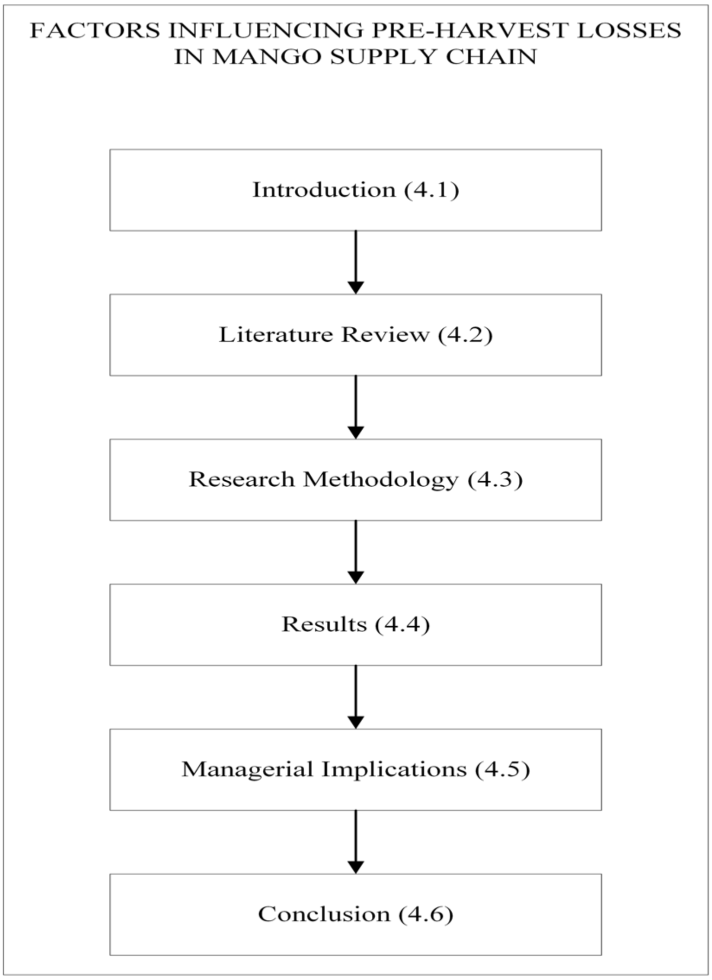


Figure 26 Overview of Chapter 4

4.1 Introduction

In the mango supply chain, losses could occur in different stages, in the pre-harvest, harvest, and post-harvest phases. The study focuses on pre-harvest losses in mango orchards. Our study excludes harvest and post-harvest stages because studies have previously been on post-harvest losses, post-harvest handling, and mango shelf life extension. Pre-harvest losses account for all the losses in the yield from the fruit set stage to the pre-mature stage. The climatic conditions, the prevalence of pests and diseases, and the physiological stress placed on the trees can lead to both qualitative and quantitative losses during the pre-harvest stage (FAO, 2017). Losses at harvest include fruit loss due to over-ripeness and damaged fruit resulting from improper harvesting practices in which the fruit is dropped directly on the ground. Harvesting losses include qualitative losses when handling immature, irregular, or bruised fruit. Post-harvest losses occur due to lengthy transportation. 10 to 15 percent of the produce is lost due to post-harvest losses because there are no nearby local markets. Quantitative losses are due to rough handling and damaged rotten fruit.

In contrast, qualitative losses are attributable to irregular ripening, softening, and breakage of the bottom layer of fruit in the load. Using suitable packaging materials and designs and maintaining regulated conditions throughout transport could help minimize losses at this point (FAO, 2018). We have shown the factors of pre-harvest losses in the conceptual framework in Figure 27. pruning, as a practice by itself, has been considered a factor. Division of fertilizer application practice has three factors: the variety of fertilizer used, application frequency, and cost. Division of pesticide application practice into three factors, including the type of pesticide application frequency and the cost of the pesticide. There needs to be more research into the significance of pre-harvest losses. This study aimed to understand the factors contributing to mango's total supply chain losses.

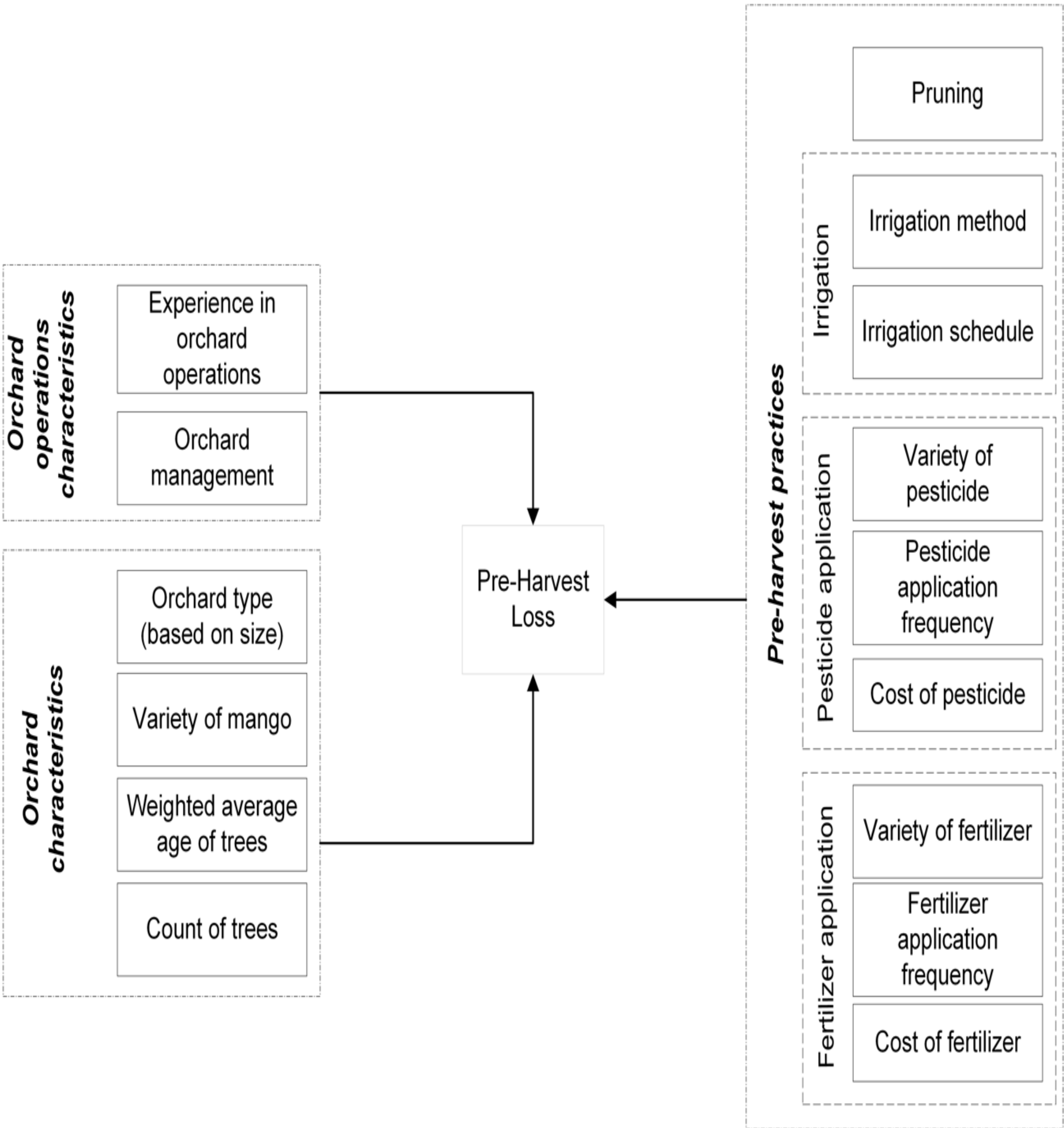


Figure 27 Conceptual Framework of Pre-Harvest Losses in the Mango Supply Chain

Understanding the factors causing the pre-harvest losses is essential as it adds to the overall loss in the mango supply chain. This study aims to identify the significant factors that affect mango supply chain losses during the pre-harvest stages. To comprehend the pre-harvest losses, we have compiled data on the percentage loss of fruits at the early and middle stages of fruit development, i.e., post-flowering fruit set stage to the pre-mature phase of fruit.

4.2 Literature Review

This section of the literature focuses on all practices in mango orchards till mandi from one harvest to another harvest cycle. Pre-harvest practices in mango orchards include pruning, irrigation, fertilizer, and pesticide application. However, pre-harvest practices have been limited from harvest to harvest cycle only; we have yet to include other aspects like planting material, planting season, and spacing of trees. We reviewed literature from the operational, horticultural, and economic perspectives to understand better.

Pruning removes a portion of a tree's branches to produce more uniform branch distribution and improve ventilation within the mango tree. S. P. Kumar et al. (2020) experimented on 'Kent' mango orchards; two pruning processes were conducted for experimentation. One technique opens the canopy to expose as much fruit to sunlight as possible, while the other produces square-shaped trees and reduces the amount of the sun reaching the fruit. This study provided evidence for the beneficial effects of sunlight on red color development without harming the harvest quality of the mango fruit.

Irrigation practices vary greatly depending on the crop, soil type, and management philosophy (Williamson and Crane, 2010). Irrigation techniques implemented in a mango orchard include the basin, furrow, drip, or sprinkler. (Schulze et al. 2013) Conducted a study that deployed micro sprinklers in two commercial mango orchards, which utilized full irrigation based on climatic water balance, deficit irrigation, and farmer-controlled scheduling. Results showed that deficit irrigation significantly boosts crop water productivity and stabilizes yield during drought. Whereas with full irrigation and micro-sprinkler usage, farmers' profit can be raised by 55%. Few similar studies conducted as a means of conserving irrigation water by (Liu *et al.*, 2021), (Lipan *et al.*, 2021), and (Spreer *et al.*, 2009) used four irrigation levels, full irrigation throughout the growth period, and regulated deficit irrigation during flowering, fruit expansion, and maturity. Full irrigation met all the crop's water requirements. Regulated deficit irrigation levels received reduced water levels with 75%, 50%, and 33% of irrigation water, respectively. Results showed that regulated deficit irrigation decreased mango size without impacting mango production. Regulated deficit irrigation at maturity increased fruit output by 10.1% in 2018 and improved average weight. Irrigation timing also affects mango yield (Zhang et al., 2019). In 2018–2019, an orthogonal mango drip fertigation experiment examined how irrigation volume and fertilizer regime affected mango harvest quantity, fruit quality, water usage efficiency, and partial fertilizer productivity. Sun et al. (2022) advised irrigation at 75% to maximize production, quality, and water–fertilizer efficiency.

Fertilizer application impacts yield and fruit quality. Azam et al. (2022) studied how nitrogen (N), phosphorus (P), and potassium (K) fertilizers affected vegetative and reproductive growth, yield, and fruit quality in mango orchards. Results showed that mango trees' fruiting, yield, physiochemical properties, and fruit quality improved after using NPK. De Mello Prado (2010) examined the nutrition and development of mango plants after fertilizing them with phosphorus. Fertilizer application raised soil phosphorus levels but only affected plant performance in the second year. After a regular application for three years, phosphorus increased the diameter of the plant's stem; however, the fruit set was unaffected.

Pesticide application is essential as farmers' anticipated yield loss due to insect pests is closely associated with pest severity (van Mele, van Huis, and Thu Cuc, 2001). According to a survey, over 47% of 820 rice, potato, bean, eggplant, cabbage, sugarcane, and mango farmers in Bangladesh used excessive pesticides. Pesticide overuse was influenced considerably by misunderstanding, income, farm ownership, chemical toxicity, crop mix, and geographic location (Dasgupta, Meisner, and Huq, 2007). The effects of a bundle of integrated pest management (IPM) practices on mango yield, mango net income, insecticide use, human health, and the environment were investigated by Kenyan mango growers. According to the data, integrated pest management adopting farmers achieve higher mango yields and net income, use less insecticide, and harm the environment and human health less. In addition, transitioning from a single IPM approach to many IPM practices produces more extensive economic, environmental, and health benefits (S. kifouly G. Midingoyi et al., 2019). Small farmers' knowledge, beliefs, and behaviors regarding mango pests and their desire to use IPM technology as a sustainable method for mango fruit fly control were examined in Ethiopia. The fruit fly was the study area's most economically significant mango pest. Fruit flies accounted for 28% of mango yield losses (Muriithi et al., 2021).

4.3 Research Methodology

This study attempts to understand the factors of pre-harvest losses in the mango supply chain in the Jangaon, Rangareddy, and Yadadri Bhuvanagiri districts of Telangana. We began by conducting a literature analysis and contacting mango orchard farmers to formulate the research questions and extract factors. As shown in Appendix, we developed a structured questionnaire, collected responses from farmers/hired managers/pre-harvest contractors, and gathered data using a face-to-face survey. We have used the software SPSS 26 And implemented various tools and techniques to analyze the data obtained. We use the Design of Experiments (DOE) approach to create an experimental design that demonstrates the individual and interaction effects of the essential factors on pre-harvest losses (D.C. Montgomery, 2013b). The subsections comprehensively describe factor identification, questionnaire development, sample size determination, and data collection processes. The questionnaire had 65 questions, taking approximately 30 minutes for respondents to complete.

Sample size and selection are critical for producing satisfactory data from questionnaire surveys. We used a stratified sampling technique for this study—each farmer's size represents one stratum. Collected responses are from all four strata, i.e., marginal, small, semi-medium, and medium. Respondent information was evaluated using version 26 of Statistical Processing for Social Science (SPSS). We used multiple linear regression to assess the key factors impacting the mango supply chain's preharvest losses. Using the design of experiments (DOE) method, we determined how significant input factors influence pre-harvest losses and identified interaction effects between the factors. We utilized JMP software to experiment.

4.4 Results

4.4.1 Multiple Regression Model on Pre-Harvest Loss

Firstly, we performed a multiple linear regression on pre-harvest losses. All the factors considered for the model on pre-harvest losses were; the variety of mango, count of trees, the weighted average age of trees, experience in orchard operations, orchard type, orchard management, district, variety of fertilizer, variety of pesticides, pesticide application frequency, cost of pesticide application. Due to the high correlation between the cost of fertilizer application to the cost of pesticide application, we dropped it. We dropped the factor representing the irrigation and fertilizer application frequency as the responses received showed no significant variation.

Table 8 summarizes the model; mainly provides the square root of R squared, which reflects the correlation between the observed and predicted values of the dependent variable pre-harvest loss. More importantly, we are interested in the R-squared value, representing the percentage of variation the model explains. According to this model, the independent variables' experience in orchard operations, orchard type- marginal and small, orchard management, district - Jangaon, and pesticide application frequency account for 26 percent of the dependent variable. While the adjusted R-squared is an adjustment of the R-squared that compensates for adding extraneous predictors, the closer the R-squared, the better. Table 8 reveals the difference between the R-square and the adjusted R-square to be only 0.015, with the standard deviation of the error component (ε) in the final column.

The focus is not on high R Square value but on identifying the significant factors. The low R Square value is due to other uncontrollable environmental factors (climate, natural disasters). Field studies have lower R square values (Wang, Liu and Qi, 2014; Singh and Verma, 2017).

Table 8 Model Summary of Pre-Harvest Losses

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.515[a]	.265	.248	.159308

Table 9 ANOVA Test on the Model of Pre-Harvest Losses

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.426	6	.404	15.930	.000
	Residual	6.725	295	.025		
	Total	9.151	301			

Table 10 Summary of the Regression for the Model of Pre-Harvest Losses

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
(Constant)	.540	.031		17.454	.000		
Experience in Orchard Operations	-.006	.001	-.244	-4.542	.000	.868	1.152
District-Jangaon	-.055	.021	-.138	-2.573	.011	.867	1.154
Orchard Management	.068	.020	.169	3.345	.001	.983	1.017
Orchard Type-Marginal	-.078	.025	-.189	-3.138	.002	.693	1.443
Orchard Type-Small	-.048	.022	-.127	-2.160	.032	.721	1.387
Pesticide application Frequency	-1.076	.188	-.298	-5.725	.000	.925	1.081

Furthermore, an ANOVA test was conducted (Table 9). The residual sum of squares is 7.641, representing the model's remaining variation. The p-value of the F-test is less than 0.05 (0.000), so the results are very significant. Consequently, the model accounts for a substantial proportion of the variation in the dependent variable pre-harvest loss. Figure 28 and Figure 29 present the histogram and normal P-P plot of pre-harvest losses.

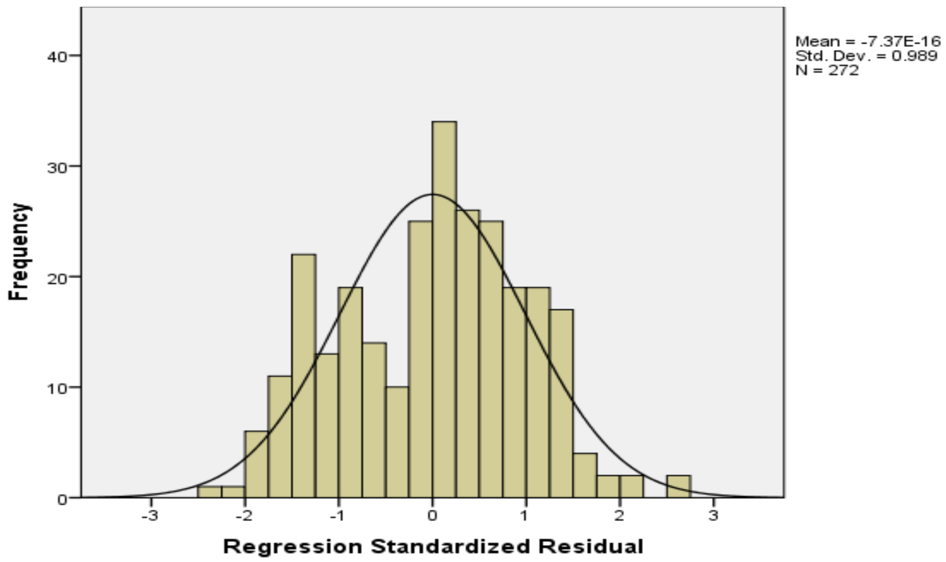


Figure 28 Histogram for Pre-Harvest Losses

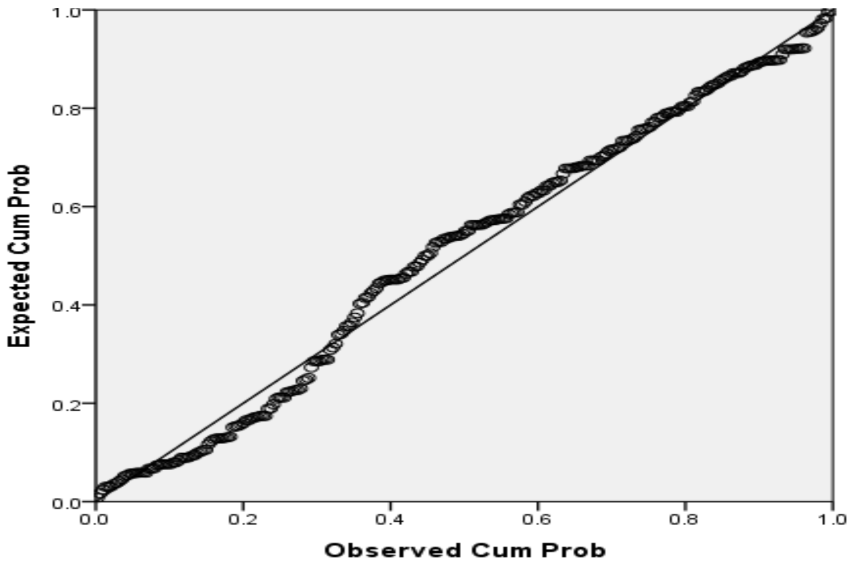


Figure 29 Normal P-P Plot for Pre-Harvest Losses

The analysis results in Table 10 represent the significant factors ($p<0.05$) experience in orchard operations, orchard type- marginal and small, orchard management, district -Jangaon, and pesticide application frequency. The Variance Inflation Factor (VIF) helps evaluate multicollinearity. All the values of factors range between 1 and 2, and there is no severe multicollinearity among the factors. There is heteroscedasticity amongst the factors.

4.4.2 Design of Experiment

When designing pre-harvest loss experiments, it is common to practice initializing significant input variables and factor levels according to the lowest and highest values recorded in the relevant historical period (D.C. Montgomery, 2013b). The regression results are the foundation for the DOE model, as shown in Figure 30. The levels of all the considerations for the study are broken down and summarised in Table 11.

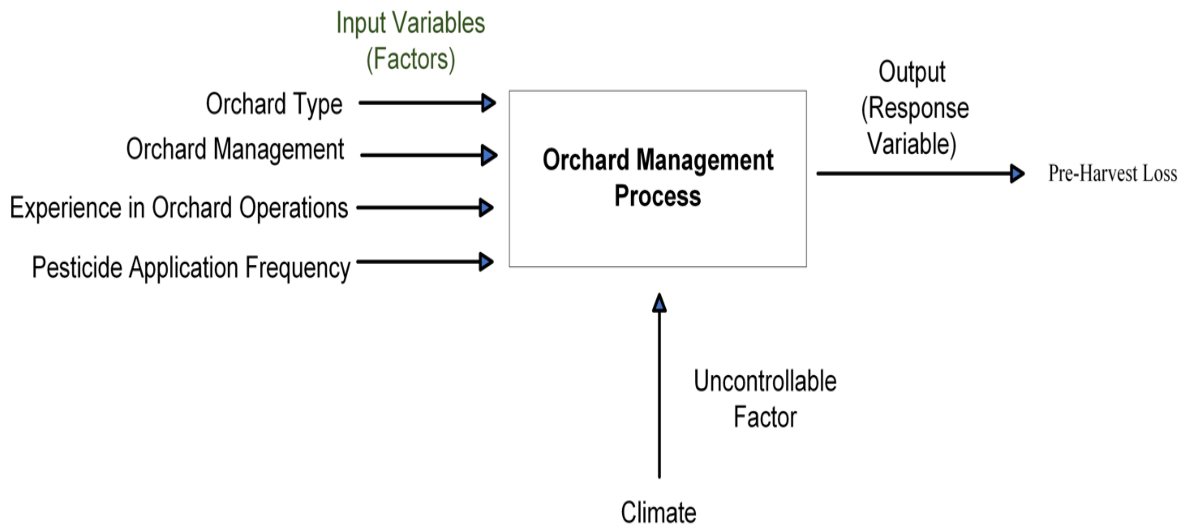


Figure 30 Orchard Management Process Model – Pre-Harvest Losses

Table 11 Input Variables for the Model – Pre-Harvest Loss (Response Variable)

Input Variables(Factors)	Number of Levels	Level 1	Level 2	Level 3	Level 4
Orchard type	4	Marginal	Small	Semi-Medium	Medium
Orchard Management	2	Hired Manager	Farmer		

Experience in orchard operations	3	Below 15 years	15 to 30 years	Above 30 years	
Pesticide Application Frequency	4	1	2	3	4

DOE is used to understand the main factor effect and interaction effect on the response variable (D.C. Montgomery, 2013b). Figure 31 is a summary of the effects of the DOE model.

The main factor effects that are significant impact on pre-harvest losses are : orchard type, orchard management, pesticide application frequency, experience in orchard operations.

Interaction factor effects that are significant impact on pre-harvest losses are: orchard type and experience in orchard operations, orchard management and experience in orchard operations, orchard type and orchard management, orchard management and pesticide application frequency, orchard type and pesticide application frequency, experience in orchard operations and pesticide application frequency.

Source	Log worth	P Value
Orchard Type*Experience in Orchard Operation	19.854	0.00000
Experience in Orchard Operation*Orchard Management	13.374	0.00000
Orchard Type	12.787	0.00000 ^
Orchard Management	12.471	0.00000 ^
Pesticide Application Frequency	12.220	0.00000
Orchard Type*Orchard Management	12.127	0.00000
Orchard Management*Pesticide Application Frequency	10.789	0.00000
Experience in Orchard Operation	7.517	0.00000 ^
Orchard Type*Pesticide Application Frequency	7.325	0.00000
Experience in Orchard Operation*Pesticide Application Frequency	6.913	0.00000

Figure 31 Effects Summary- Design of Experiments for Pre-Harvest Losses

Orchard type has the highest main factor effect on pre-harvest losses. The interaction effect between orchard type and experience in orchard operations has the highest effect on pre-harvest losses.

Figure 33 depicts the variance analysis and for the DOE run on pre-harvest losses in mango orchards. The F value of the model is less than 0.05, suggesting the overall DOE model is significant. A considerable fraction of the observed variation explains the model (higher value of the model sum of squares). Figure 33 depicts the parameter estimations, a p-value that is less than 0.05. Prior observations suggest that the findings about their effect on pre-harvest losses and the conclusion drawn from this data are statistically significant. From parameter estimations, we infer that multiple factors and their interactions determine pre-harvest loss.

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	25	2056.7502	82.2700	82.9042
Error	174	172.6690	0.9924	**Prob > F**
C. Total	199	2229.4191		<.0001*

Figure 32 Analysis of Variance for Pre-Harvest Losses

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.8216068	0.176492	4.66	<.0001*
Orchard Type[Marginal]	0.9300931	0.122128	7.62	<.0001*
Orchard Type[Small]	- 1.111739	0.122109	-9.10	<.0001*
Orchard Type[Semi-Medium]	1.0597341	0.122128	8.68	<.0001*
Orchard Management[Hired Manager]	0.9829296	0.070532	13.94	<.0001*
Experience in Orchard Operation[Below 15]	0.5919596	0.099989	5.92	<.0001*
Experience in Orchard Operation[15 to 30]	- 0.870625	0.099336	-8.76	<.0001*
Pesticide Application Frequency(0.08,0.33)	0.9368944	0.077811	12.04	<.0001*
Orchard Type[Marginal]*Orchard Management[Hired Manager]	0.9372792	0.122167	7.67	<.0001*

Term	Estimate	Std Error	t Ratio	Prob>|t|
Orchard Type[Small]*Orchard Management[Hired Manager]	-1.06643	0.122166	-8.73	<.0001*
Orchard Type[Semi-Medium]*Orchard Management[Hired Manager]	-0.96466	0.122167	-7.90	<.0001*
Orchard Type[Marginal]*Experience in Orchard Operation[Below 15]	0.4683216	0.17246	2.72	0.0073*
Orchard Type[Marginal]*Experience in Orchard Operation[15 to 30]	1.3742764	0.171924	7.99	<.0001*
Orchard Type[Small]*Experience in Orchard Operation[Below 15]	-0.854519	0.174119	-4.91	<.0001*
Orchard Type[Small]*Experience in Orchard Operation[15 to 30]	-0.946716	0.171923	-5.51	<.0001*
Orchard Type[Semi-Medium]*Experience in Orchard Operation[Below 15]	-0.701759	0.17246	-4.07	<.0001*
Orchard Type[Semi-Medium]*Experience in Orchard Operation[15 to 30]	-1.260314	0.171924	-7.33	<.0001*
Orchard Type[Marginal]*Pesticide Application Frequency	1.0100299	0.134741	7.50	<.0001*
Orchard Type[Small]*Pesticide Application Frequency	-1.09264	0.134831	-8.10	<.0001*
Orchard Type[Semi-Medium]*Pesticide Application Frequency	1.1094353	0.134741	8.23	<.0001*
Orchard Management[Hired Manager]*Experience in Orchard Operation[Below 15]	1.0071892	0.100002	10.07	<.0001*
Orchard Management[Hired Manager]*Experience in Orchard Operation[15 to 30]	0.8870451	0.099281	8.93	<.0001*
Orchard Management[Hired Manager]*Pesticide Application Frequency	1.0782693	0.077769	13.87	<.0001*
Experience in Orchard Operation[Below 15]*Pesticide Application Frequency	0.9349437	0.11078	8.44	<.0001*
Experience in Orchard Operation[15 to 30]*Pesticide Application Frequency	-0.82036	0.108792	-7.54	<.0001*
Pesticide Application Frequency*Pesticide Application Frequency	1.1855546	0.197291	6.01	<.0001*

Figure 33 Parameter Estimates for Pre-Harvest Losses

Figure 34 depicts the Prediction Profiler lets you interactively examine the impact on your response variable when you change individual factor level settings while the other factors are held constant (D.C. Montgomery, 2013b). In Figure 34 response variable (pre-harvest loss) is on Y-axis, and the factors are on X-axis. The prediction profiler shows all four-factor level settings for pre-harvest loss values. The vertical red line in the Prediction profiler for marginal orchard (Figure 34) is at farmer level (for farmer factor), at 15 to 30 years (for experience in orchard operations factor), and at 1 (for pesticide application frequency factor) representing the optimal level. The vertical red line in the Prediction profiler for small orchard (Figure 35) is at farmer level (for farmer factor), at 15 to 30 years (for experience in orchard operations factor), and at 1 (for pesticide application frequency factor) representing the optimal level. The function of desirability is measured on a scale of 0 to 1, where 1 represents the outcome that is considered the most desirable. The function of desirability is employed to evaluate the adequacy of the model in terms of its conformity to the data and its ability to forecast results. The pre-harvest loss model that has been developed in this case is deemed highly desirable, as indicated by its desirability score of 0.999 for both marginal and small orchards (D.C. Montgomery, 2013b).

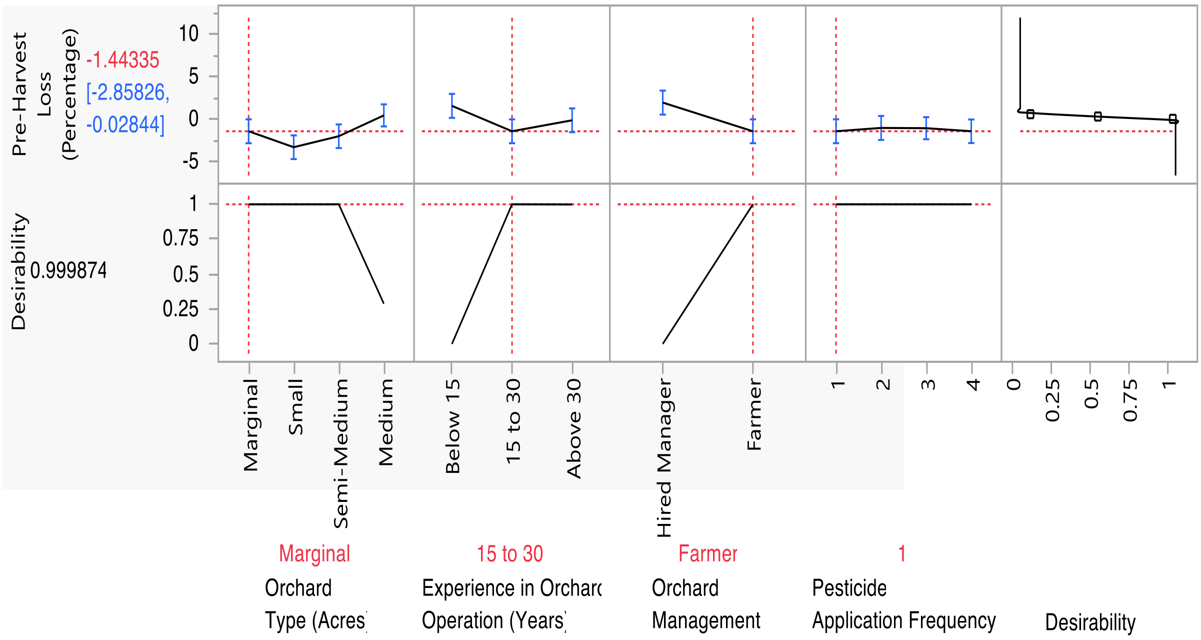


Figure 34 Prediction Profiler - Marginal Orchard for Pre-Harvest Losses

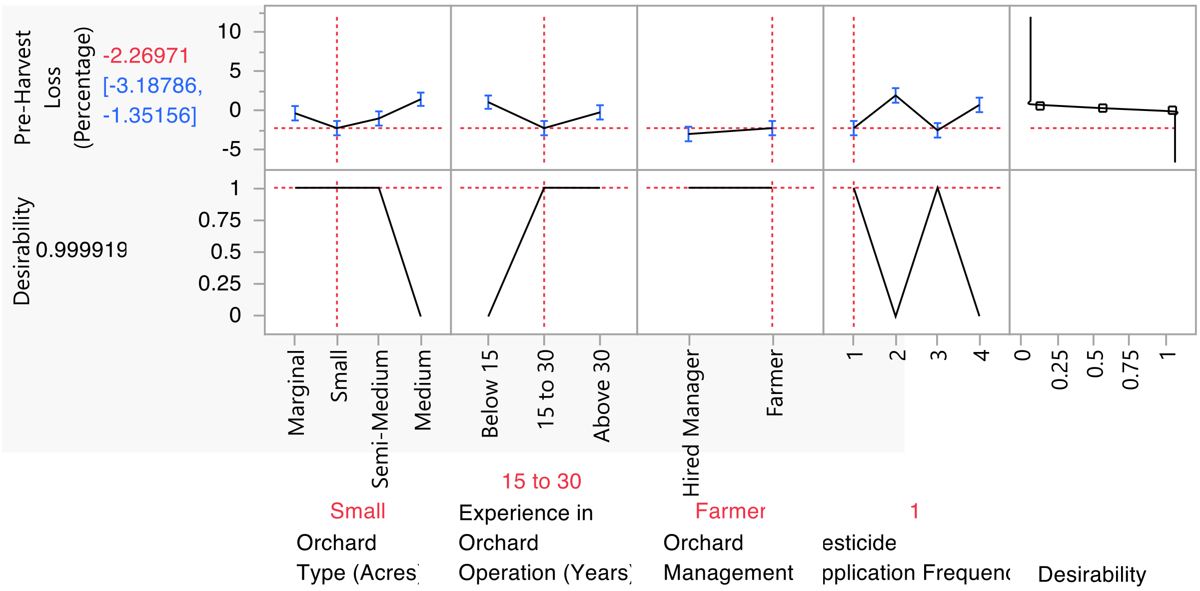


Figure 35 Prediction Profiler- Small Orchard for Pre-Harvest Losses

4.5 Managerial Implications

Over 92% of the overall population in the study area consists of marginal (80%) or small (12%) sized orchards, identifying factors impacting pre-harvest losses will benefit the farmers in reducing losses. After conducting the study we have deduced the following guidance(Table 12) and implications to marginal and small orchard farmers.

Table 12 Guidance to Marginal and Small Orchard Farmers

Factors	Guidance to Marginal and Small Orchard Farmers
Pesticide Application Frequency	Once a year based on the requirement.
Orchard Management	Orchard needs to be managed by farmer only
Experience in Orchard Operations	Preferable with 15 to 30 years of experience.

As per the discussions with experts, spraying pesticides before and during the flowering season decreases pests and insects. Farmers have also stated that older trees require more pesticides than younger trees. Our findings suggest that increasing pesticide application frequency once based on the requirement in the orchard will help reduce the pre-harvest losses.

Farmers or hired managers often manage mango orchards. A farmer must perform all the pre-harvest practices properly to reduce losses at the orchard. To verify the results, we have contacted the farmers, who have responded that there is usually a slight difference in the management of orchards. Farmers believe they manage the orchard more effectively than a hired manager, and hired managers tend to work effectively under supervision. Our findings suggest that orchards managed by farmers help in reducing pre-harvest losses.

We contacted experts such as farmers and horticultural officials to validate our findings. According to experts, amongst all the four orchard types, farmers owing marginal-sized orchards manage better to have reduced pre-harvest losses.

We inferred that farmers hired managers and pre-harvest contractors with 15–30 years of experience to help reduce pre-harvest losses. Experts said it is hard to minimize losses even with more than 30 years of experience due to a lack of knowledge of new procedures or adherence to an old practice. Our study suggests that even with more experience, farmers must adapt to advancements to mitigate these losses.

The interaction effect amongst two factors that impact pre-harvest losses is as follows: orchard management and orchard type; pesticide application frequency and orchard management; orchard management and experience in orchard operations; pesticide application frequency and orchard type; orchard type and experience in orchard operations.

4.6 Conclusion

Mango is one of India's most widely produced fruits. Mango orchard operations considerably impact fruit harvest quality and supply chain losses. According to the available literature, additional research must be conducted on preharvest losses. This research seeks to identify the pre-harvest loss factors in the mango supply chain.

The first objective of this study is to investigate the factors influencing pre-harvest losses in the mango supply chain and to provide recommendations to mango cultivators. This chapter accomplishes its purpose by identifying significant factors and providing guidance to both orchard managers and small producers. A conceptual framework was developed to identify the factors that affect mango supply chain losses. We extracted 15 potential determinants from a literature review and interviews with experts. Experience in orchard operations, orchard type - marginal and small, orchard management, district -Jangaon, and pesticide application frequency impacted pre-harvest losses, according to the initial regression model. We designed experiments to determine the factor effect and interaction effect on pre-harvest losses based on these significant factors. Interactions between factors influenced pre-harvest losses, including orchard management and orchard type; pesticide application frequency and orchard management; orchard management and orchard operations experience; pesticide application frequency and orchard type; orchard type and orchard operations experience; and orchard management and orchard type.

5 CHAPTER: FACTORS INFLUENCING HARVEST LOSSES IN THE MANGO SUPPLY CHAIN

This chapter provides an overview of the factors that impact harvest losses in the mango supply chain. There are six sections in this chapter. This chapter is introduced in the first portion. Following that, a review of the literature on pre-harvest procedures is offered. The following section describes the research methods for this study. The study's findings are then presented utilizing multiple regression and the design of trials. Lastly, in this chapter, managerial implications and concluding remarks are addressed. Figure 34 displays a visual summary of this chapter.

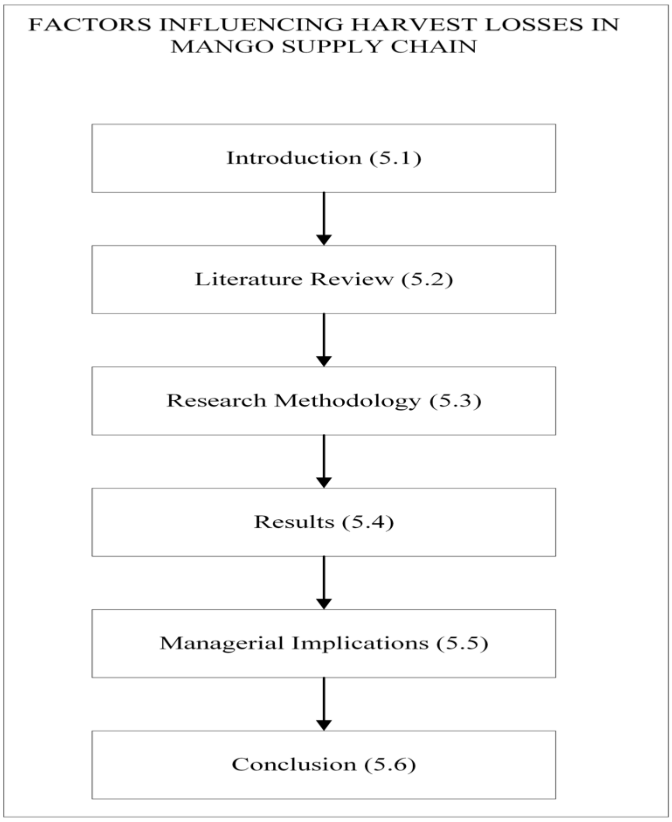


Figure 36 Overview of Chapter 5

5.1 Introduction

According to Food and Agriculture Organization, Horticulture is the branch of plant agriculture that concentrates on garden crops, vegetables, fruits, and ornamental plants. Horticulture is derived from the Latin words hortus, meaning "garden," and colere, meaning "to cultivate." Over ninety percent of India's horticulture production consists of fruits and vegetables. India is the world's second-largest producer of vegetables and fruits and the first in various horticulture products, such as mango, papaya banana, areca nut, cashew nut, okara, and potato(FAO, 2018). Telangana is the sixth-largest mango-producing state in India. We have selected three districts in Telangana to conduct this study: Jangaon, Rangareddy, and Yadadri Bhuvanagiri. The Ministry of Agriculture and Farmer's Welfare of the Government of India classifies Indian farmers into five groups based on their orchard acreage: marginal, small, semi-medium, medium, and large (Ministry of Agriculture & Farmers Welfare, 2019). Eighty percent of the farmers in the study area are marginal, twelve percent are small, six percent are semi-medium, and two percent are medium.

The harvesting procedure primarily determines mango post-harvest management. Mangoes are harvested based on their ripeness, and the farmer chooses to pick them early in the morning to minimize their exposure to sunlight after harvesting (Gómez-Lagos et al., 2021). Mango losses could occur during the pre-harvest, harvest, and post-harvest phases. This study focuses on losses during the harvesting stage. Harvest losses include loss owing to over-ripeness and fruit damage caused by incorrect harvesting techniques in which the fruit is dropped directly on the ground. When handling immature, uneven, or damaged fruit, harvesting losses include reduced fruit harvest quality. Harvest losses result when the farmer decides to pick the fruit when there are already many overripe fruits on the tree.

Figure 35 presents the conceptual framework. In understanding harvest losses, we have compiled data on the percentage of fruits lost due to over-ripeness, i.e., unpicked fruit after reaching maturity. Respondents include farmers (orchard owner), hired managers (work for orchard owner), and pre-harvest contractors (take lease of the orchard from the owner). This study would help to educate marginal and small farmers about the essential practices they now adopt and how to minimize losses. Losses could occur in different stages, in the pre-harvest, harvest, and post-harvest stages. The study focuses on harvest losses in mango orchards. Our study excludes post-harvest stages because there have previously been studies on post-harvest losses, post-harvest handling, and mango shelf-life extension.

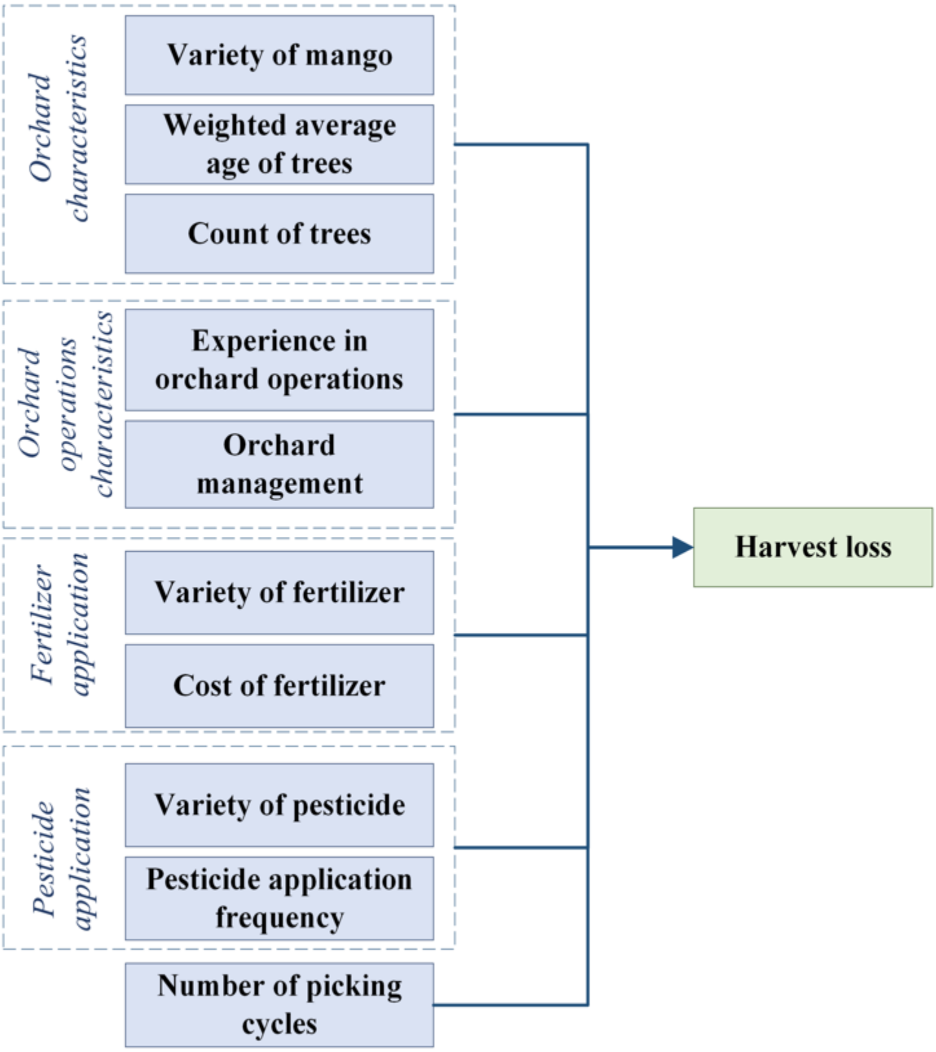


Figure 37 Conceptual Framework of Harvest Losses in the Mango Supply Chain

5.2 Literature Review

Pruning removes a portion of a tree's branches to achieve a more uniform branch distribution and improve the ventilation of the mango tree. Reference (Kumar *et al.*, 2020b) conducted experiments on 'Kent' mango orchards using two pruning processes. The first method exposes as much mango as possible to sunlight, while the second method produces square-shaped trees and reduces the amount of sunlight that reaches the fruit. This study demonstrated the beneficial effect of sunlight on the development of red pigmentation in mango fruit without compromising its harvest quality.

The irrigation techniques vary significantly based on the crop, soil composition, and management commitment (Williamson and Crane, 2010). Reference (Schulze et al., 2013) conducted an experiment in which micro sprinklers were installed in two distinct mango orchards using full irrigation by climatic water balance, deficit water supply, and farm owner frequency. The results indicated that drip irrigation increases crop water productivity and stabilizes yields during drought. Farmers can increase their profitability by 55% with complete irrigation and micro-sprinklers. Reference (Spreer et al., 2009; Lipan et al., 2021; Liu et al., 2021) utilized four watering levels to conserve irrigation water, including irrigation throughout the growth phase and controlled deficit irrigation during flowering, fruit growth, and maturity. Full irrigation satisfied the crop's water requirements and controlled water deficit reduced mango size without affecting mango yield. Due to controlled deficit irrigation at maturity, fruit yield increased by 10.1% in 2018, while average fruit weight rose. Irrigation timing also affects mango yield (Zhang, Wang, and Li, 2019).

To maximize the yield, quality, and efficiency of water and fertilizer for mangoes, a 75% irrigation rate is optimal(Sun et al., 2022)—the application of fertilizer influences crop yield and fruit quality. Reference (Azam et al., 2022) studied the effects of phosphorus (P), nitrogen (N), and potassium (K) fertilizers on the reproductive and vegetative growth, yield, and fruit quality of mango orchards. Mango trees exhibited increased yield, fruiting, physicochemical characteristics, and fruit quality following the application of NPK. Reference (de Mello Prado, 2010) examined the nutrition and growth of mango plants when fertilized with phosphorus. Phosphorus increased the size of the plant's stem after three years of consistent application but did not affect the fruit set. Phosphorus increased the size of the plant's stem after three years of constant application but did not affect the fruit set.

Due to the close relationship between insect pests and pest severity, farmers anticipated an association between pesticide use and crop yield (van Mele, van Huis, and Thu Cuc, 2001). According to a survey, over 47% of 820 potatoes, rice, bean, cabbage, eggplant, sugarcane, and mango farm owners in Bangladesh used large amounts of pesticide. Misconception, income, farm ownership, crop mixture, chemical toxicity, and location greatly influence pesticide misapplication (Dasgupta, Meisner, and Huq, 2007). Based on the information, farmers who employ integrated pest control have increased mango yields and net earnings, use less pesticide, and have a negligible negative impact on the environment and public health.

Furthermore, transitioning from a common IPM strategy to several IPM practices produces macroeconomic, environmental, and health advantages (S. kifouly G. Midingoyi et al., 2019). In Ethiopia, small farmers' awareness, beliefs, and behavioral patterns concerning mango pests and willingness to use IPM practices as a sustainable option for mango fruit fly influence were investigated. In the study region, the fruit fly constituted the most economically beneficial mango pest. The previous study shows that 28% of the decline in mango yield is due to fruit flies (Muriithi et al., 2021).

According to Reference (Gómez-Lagos et al., 2021), picking all through the harvest season is contingent on the days following full flower initiation. They are the most important for commercial fruit consumption. The findings showed that the ideal time for customer satisfaction is between 126 and 133 days upon flower initiation. Reference (Chen and Chen,

2021) implemented a stochastic optimization model to study the picking decisions throughout a harvest season to minimize the forecasted cost of labor, shelf life, storage space, and transportation limitations. Mango harvesting is more labor-intensive in June than in July and August since farmers harvest naturally ripe mangoes in June. Reference (Escallón-Barrios et al., 2022) described an end-to-end analytics strategy comprised of data diagnosis, descriptive (simulation), and prescriptive (optimization) techniques to enhance harvest operations in the mango agricultural system and included strategic (harvest season), tactical (resource distribution), and operational models (transport allocation). Moreover, we have developed alternative operational solutions that decrease the average harvest time from 19.6 to 8.2 days.

Mangoes require de-stemming after harvesting, and the quality of the mango diminishes due to the sap that outpours from the stem after removal, causing sap burn on the fruit's outer layer. Reference (Barman et al., 2015) investigated desapping techniques on Chausa, a variety of mango; closely after harvesting, the fruits were treated after de-stemmed with several desapping agent solutions. Soon after being treated, the mangoes were air-dried and stored for 12 days at a constant room temperature (302 °C). The treatment uses sodium hydroxide (1%) reduced sap burn over other treatment techniques. The study and therapy highly increased the mango's shelf life by reducing the ripening process due to reduced ethylene emission and respiration rates.

DOE is a method of applied statistics for determining the relationship between the /variables impacting a process and its output/response (D.C. Montgomery, 2013b). DOE permits the simultaneous manipulation of numerous variables and the estimation of their effects on a response variable. Using the DOE technique, the current objective of this investigation is to identify the impacting harvest losses. In historical studies, the application of the DOE approach to comprehend the impact and interplay of mango orchard harvest losses is quite scarce.

5.3 Research Methodology

The DOE method is used to gain knowledge of the relevance of the influencing variables (factors) and the degree (levels) to which they contribute to harvest losses in mango orchards. Within the scope of our research, we found that 92% of the population owned marginal or small orchards. Only these orchards are the subject of our study, and 205 respondents —including farmers, hired managers, and pre-harvest contractors—were part of the survey. Only these orchards are the subject of our study, which includes a sample of 205 respondents, including farmers, hired managers, and pre-harvest contractors. Each factor extracted from a literature review and conversations with experts, such as farmers and horticulture officials, provided the studies. As part of the questionnaire preparation, we first contacted 25 farmers and three horticulture officials from the study area. We have developed open-ended questions for experts to help comprehend the mango orchard's operations. Multiple regression approaches are employed to identify the significant factors considered during the DOE run.

After conducting an exhaustive literature review and interviewing mango orchard growers, we designed a structured questionnaire. The questionnaire contains factors that impact harvest losses. We designed the questionnaire in English and translated the final version into Telugu (regional language). Following the pre-testing, we revised the questionnaire and conducted a pilot study to assess its validity. The pilot study comprised 27 farmers from the study area, and the final version of the questionnaire required additional adjustments. The final version of the questionnaire had 65 questions and took respondents around 30 minutes to complete. By visiting mango orchards, we conducted a field survey. Through face-to-face interviews, we acquired data from the three districts. Before data collection, we observed farmers, hired managers, and pre-harvest contractors managing the orchards and included them as respondents. According to the results from regression analysis, three were significant:

experience in orchard operations, pesticide application frequency, and the number of picking cycles.

5.4 Results

5.4.1 Multiple Regression Model on Harvest Losses

We conducted a multiple linear regression analysis to examine the harvest losses. We analyzed 205 responses from the Jangaon, Rangareddy, and Yadadri Bhuvanagiri districts of Telangana. All independent variables evaluated for the harvest loss model were the following: the variety of mango, the weighted average age of trees, the count of trees, experience in mango orchard operations, orchard management, fertilizer type, cost of fertilizer, pesticide type, pesticide application frequency, and the number of picking cycles. We excluded the irrigation and fertilizer application frequency in a year due to the lack of substantial variance in the responses. Also, we removed pesticide costs from the analysis due to the high correlation with fertilizer costs.

More significantly, the R-squared value shows the percentage of variation explained by the model. The significant independent variables, contribute to 24.1 percent of the dependent variable in this model. At the same time, the adjusted R-squared is an R-squared modification that accounts for adding extraneous predictors; the closer the R-squared, the better. The difference in Table 12 is only 0.015, with the standard deviation of the error component (ε) in the final column.

Furthermore, an ANOVA test was conducted (Table 13). The residual sum of squares is 0.647, showing the remaining variation in the fitted model. The F-test p-value is less than 0.05 (0.000), indicating that the results are highly significant. Consequently, we can argue that the model accounts for a sizeable amount of the harvest loss variance.

Table 13 Model Summary of Harvest Losses

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.489	.239	.228	.04993

Table 14 ANOVA Test on the Model of Harvest Losses

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.158	3	0.053	21.078	.000
	Residual	0.501	201	0.002		
	Total	0.659	204			

Table 15 Summary of the Regression on the Model of Harvest Losses

Model	Standardized Coefficients	t	Sig.	Collinearity Statistics	
	Beta			Tolerance	VIF
(Constant)		5.425	.00		
Experience in orchard operations	-0.23	-3.60	.00	0.91	1.09
Pesticide application frequency	-0.27	-4.23	.00	0.92	1.07
Number of picking cycles	0.31	4.84	.00	0.88	1.12

Table 14 displays the critical ($p<0.05$) experience in orchard operations ($p = 0.00$), pesticide application frequency ($p = 0.00$), and the number of picking cycles ($p = 0.00$). The Variance Inflation Factor (VIF) aids in assessing multicollinearity. All VIF values are between 1 and 1.2, suggesting no substantial multicollinearity among variables. Figure 36 and Figure 37 present the histogram and normal P-P plot of harvest losses.

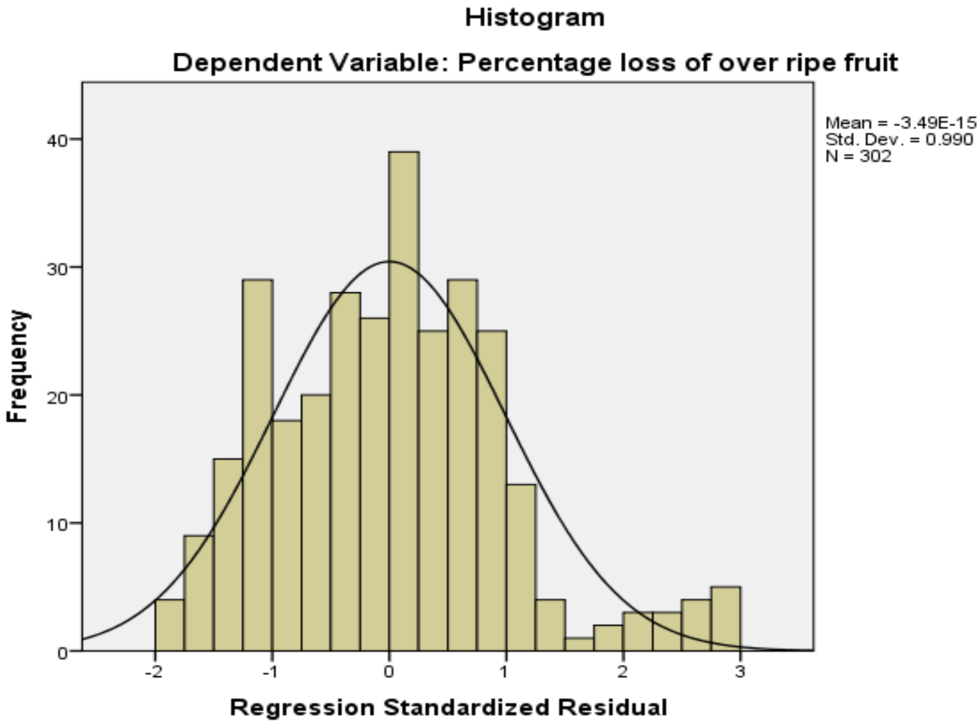


Figure 38 Histogram for Harvest Losses

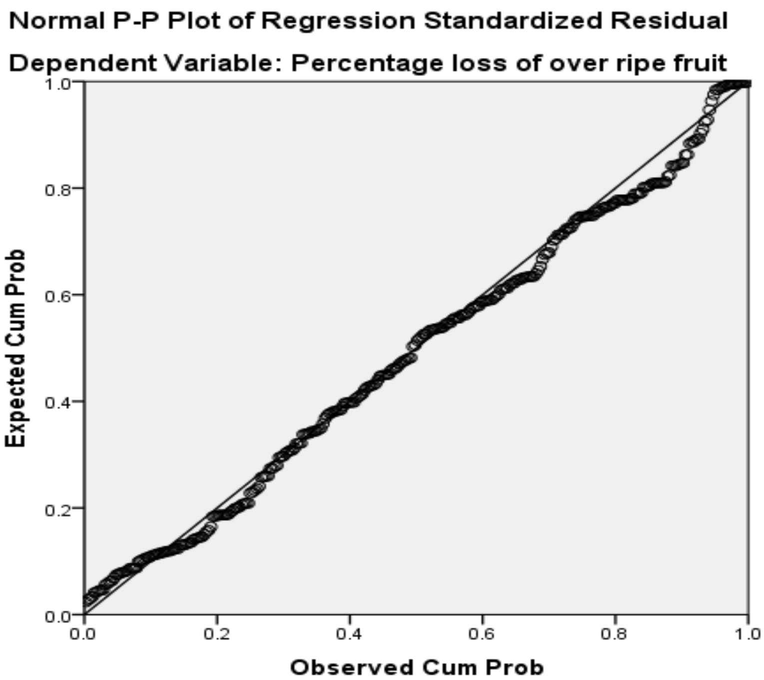


Figure 39 Normal P-P Plot for Harvest Losses

5.4.2 Design of Experiments

Design of Experiments for harvest losses is conducted (D.C. Montgomery, 2013) with identified significant input variables and factor levels set at historical Minimum and Maximum levels. The regression results are the DOE model's foundation (Figure 38). Table 15 summarizes the levels of all the considerations for the study. Figure 39 summarizes the effects summary of the DOE run. The number of picking cycles, pesticide application frequency, and experience in orchard operations influence harvest losses. In addition, the interaction between the number of picking cycles, pesticide application frequency, and experience in orchard operations also significantly affects harvest losses.

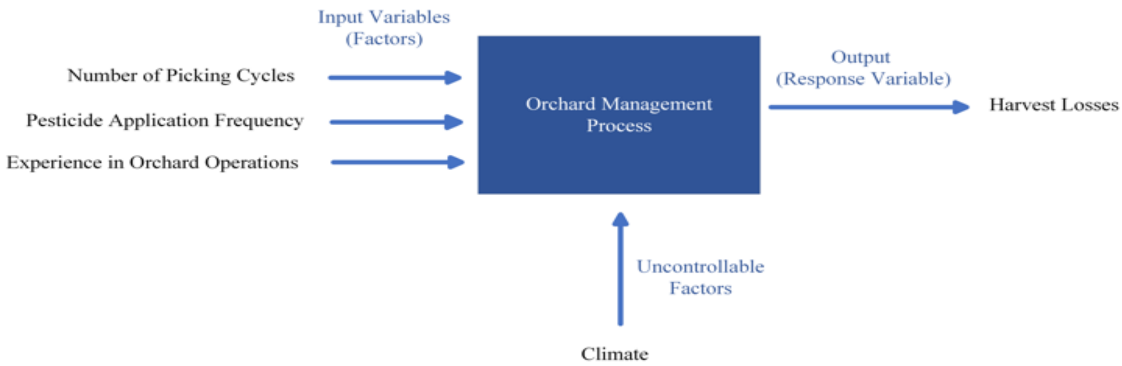


Figure 40 Orchard Management Process Model – Harvest Losses

Table 16 Input Variables for the Model – Harvest Losses (Response Variable)

Input Variables	Number of Levels	Levels			
		Level 1	Level 2	Level 3	Level 4
Experience in Orchard Operations	3	Below 15 years	16 to 30 years	Above 30 years	
Pesticide Application Frequency	4	1	2	3	4
Number of Picking Cycles	3	1	2	3	

DOE is used to understand the main factor effect and interaction effect on the response variable (D.C. Montgomery, 2013b). Figure 41 is a summary of the effects of the DOE model.

The main factor effects that are significant impact on harvest losses are : number of picking cycles, pesticide application frequency, experience in orchard operations.

Interaction factor effects that are significant impact on harvest losses are: experience in orchard operations and pesticide application frequency, number of picking cycles and experience in orchard operations, number of picking cycles and pesticide application frequency.

Source	Logworth	PValue
Pesticide Application Frequency*Experience in Orchard Operations	40.155	0.00000
Number of Picking Cycles*Experience in Orchard Operations	31.180	0.00000
Pesticide Application Frequency	25.447	0.00000 ^
Experience in Orchard Operations	22.878	0.00000 ^
Number of Picking Cycles	15.594	0.00000 ^
Number of Picking Cycles*Pesticide Application Frequency	14.035	0.00000

Figure 41 Effects Summary Design of Experiments for Harvest Losses

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	23	1242.0752	54.0033	49.2722
Error	176	192.8994	1.0960	Prob > F
C. Total	199	1434.9746		<.0001*

Figure 42 Analysis of Variance for Harvest Losses

The variance analysis and the outcomes of the DOE run on harvest losses in mango orchards are shown in Figure 41. The overall significance of the DOE model can be inferred from the fact that the model's F value is less than 0.05. The higher value of the model's sum of squares shows that a larger amount of the observed variation can be explained by the model. Figure 42 may be used to display the parameter estimations, which have a p-value less than 0.05. According to earlier observations, the conclusions regarding their impact on harvest losses and the inference that can be made from this data seem to have statistical significance. The parameter estimates allow us to deduce the reasons of harvest losses as well as the correlations between these elements.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.9823798	0.074099	13.26	<.0001*
Number of Picking Cycles[1]	0.771041	0.104805	7.36	<.0001*
Number of Picking Cycles[2]	-0.922469	0.105121	-8.78	<.0001*
Pesticide Application Frequency[1]	0.9908355	0.128422	7.72	<.0001*
Pesticide Application Frequency[2]	-1.109716	0.12849	-8.64	<.0001*
Pesticide Application Frequency[3]	0.9589692	0.12849	7.46	<.0001*
Experience in Orchard Operations[Below 15]	1.1140334	0.104805	10.63	<.0001*
Experience in Orchard Operations[15 to 30]	-1.068869	0.105121	-10.17	<.0001*
Number of Picking Cycles[1]*Pesticide Application Frequency[1]	0.7473713	0.182939	4.09	<.0001*
Number of Picking Cycles[1]*Pesticide Application Frequency[2]	-0.75915	0.18122	-4.19	<.0001*
Number of Picking Cycles[1]*Pesticide Application Frequency[3]	1.0019401	0.181083	5.53	<.0001*
Number of Picking Cycles[2]*Pesticide Application Frequency[1]	-0.670654	0.181259	-3.70	0.0003*
Number of Picking Cycles[2]*Pesticide Application Frequency[2]	0.8184109	0.183178	4.47	<.0001*
Number of Picking Cycles[2]*Pesticide Application Frequency[3]	-1.109441	0.183178	-6.06	<.0001*
Number of Picking Cycles[1]*Experience in Orchard Operations[Below 15]	0.7606998	0.147677	5.15	<.0001*
Number of Picking Cycles[1]*Experience in Orchard Operations[15 to 30]	-0.849491	0.148769	-5.71	<.0001*
Number of Picking Cycles[2]*Experience in Orchard Operations[Below 15]	1.2374026	0.148769	8.32	<.0001*
Number of Picking Cycles[2]*Experience in Orchard Operations[15 to 30]	-1.124868	0.148937	-7.55	<.0001*
Pesticide Application Frequency[1]*Experience in Orchard Operations[Below 15]	1.2746543	0.181207	7.03	<.0001*
Pesticide Application Frequency[1]*Experience in Orchard Operations[15 to 30]	-1.308623	0.181259	-7.22	<.0001*
Pesticide Application Frequency[2]*Experience in Orchard Operations[Below 15]	0.7092709	0.18122	3.91	0.0001*
Pesticide Application Frequency[2]*Experience in Orchard Operations[15 to 30]	-0.80164	0.183178	-4.38	<.0001*
Pesticide Application Frequency[3]*Experience in Orchard Operations[Below 15]	1.0356487	0.181083	5.72	<.0001*
Pesticide Application Frequency[3]*Experience in Orchard Operations[15 to 30]	-0.91901	0.183178	-5.02	<.0001*

Figure 43 Parameter Estimates for Harvest Losses

Figure 44 depicts the Prediction Profiler lets you interactively examine the impact on your response variable when you change individual factor level settings while the other factors are held constant (D.C. Montgomery, 2013b). In Figure 34 response variable (harvest loss) is on Y-axis, and the factors are on X-axis. The vertical red line in the Prediction (Figure 44) is at two picking cycles, with 15 to 30 years experience in orchard operations, and at one pesticide application frequency representing the optimal level.

A scale from 0 to 1 is used to rate the function of desirability, with 1 denoting the most desirable outcome. In order to assess the model's suitability in terms of data conformance and outcome prediction, the function of desirability is used. The desirability score of 0.999 for the pre-harvest loss model established in this scenario indicates that it is highly desirable (D.C. Montgomery, 2013b).

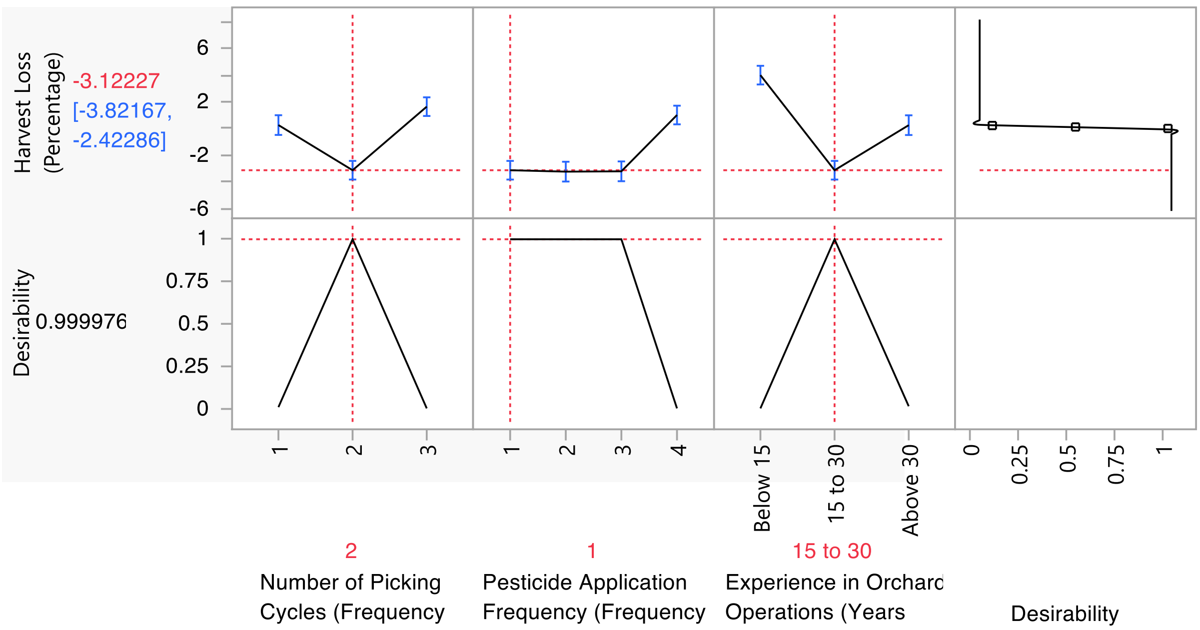


Figure 44 Prediction Profiler for Harvest Losses

5.5 Managerial Implications

Finding the factors affecting harvest losses would help farmers reduce losses because over 92% of the population in the research area is comprised up of small (12%) or marginal (80%) sized orchards. Following the completion of the study, we arrived at the following recommendations and consequences for marginal and small orchard farmers (Table 17).

Table 17 Guidance to Marginal and Small Orchard Farmers

Factors	Guidance to Marginal and Small Orchard Farmers
Pesticide Application Frequency	Once a year based on the requirement
Number of Picking Cycles	Two picking cycles in a year
Experience in Orchard Operations	Preferable with 15 to 30 years of experience

Findings indicate that the experience in orchard operations influences harvest losses. We reached out to the farmers to confirm our findings. Farmers assert that harvest losses resulted from a need for more awareness of new methods or adherence to conventional practices. Experience in orchard operations of 15 to 30 years helps to reduce the harvest losses from the results.

The frequency of pesticide application was a significant factor in harvest losses. Pesticide spray, before and during the flowering period, reduces infestations and insects, according to discussions with experts. Additionally, farmers have asserted that mature trees require more pesticides than younger trees. This research will enable farmers to comprehend the significance of scheduling pesticide applications to prevent harvest losses. Pesticide application frequency once in a year minimizes harvest losses.

The results show that the number of picking cycles determines the effect on harvest losses. After reaching the complete, mature stage, the mango fruit remains on the tree without being harvested, resulting in a loss due to over-ripeness. The survey responses suggested that the total count of picking cycles ranges from one to three. For further affirmation, we approached the farmers addressing the results, and they agreed that the two picking cycles, will help decrease the harvest losses at the orchard level.

The interaction effect of factors on harvest losses are also observed between the number of picking cycles and experience in orchard operation, the number of picking cycles and pesticide application frequency, pesticide application frequency, and orchard operations.

5.6 Conclusion

Mango is one of India's most produced fruits. Mango orchard operations significantly impact the harvest quality of the fruit and losses in the supply chain. Literature indicates a gap exists in significant research on losses during the pre-harvest and harvest stages. This research seeks to identify the factors of harvest losses, mainly in mango orchards. We developed a conceptual framework using ten potential factors from literature analysis and in-depth interviews with horticulture professionals.

The second objective of this study is to investigate the factors influencing harvest losses in the mango supply chain and to provide recommendations to mango cultivators. This chapter accomplishes its purpose by identifying significant factors and providing guidance to both orchard managers and small producers. We designed a structured questionnaire for face-to-face interviews with the target respondents, including pre-harvest contractors, farmers, and hired managers. We received an aggregate of 205 responses from marginal and small farmers. SPSS v26 is the statistical software employed for analysis in this study. To comprehend the harvest losses in the operations of the mango orchard, we performed data cleaning, feature engineering, and multiple regression. Significant factors identified from multiple regression have been used as a base for the DOE model. We have selected the factors influencing harvest losses, including experience in mango orchard management, pesticide application frequency, and the number of picking cycles. Results present the factor effect and interaction effect on harvest losses. The implications of this research for farmers are also numerous.

Future research can focus on pre-harvest and harvest fruit losses. It is possible to conduct more research on type farmers and increase awareness of small and marginal farmers. The sustainability of the mango supply chain needs analysis. Additionally, mango yield management, other fruits, and technological applications in mango require further research.

6 CHAPTER: FACTORS INFLUENCING HARVEST QUALITY IN THE MANGO SUPPLY CHAIN

This chapter overviews the factors influencing harvest quality in the mango supply chain. The chapter is divided into six sections. The first section provides an introduction to this chapter. Next, a literature review on pre-harvest practices is presented. The research methodology for this study is provided in the following section. Following that, the study's results are provided using multiple regression and the design of experiments. Finally, managerial implications and concluding remarks in this chapter are presented. Figure 42 depicts a visual overview of this chapter.

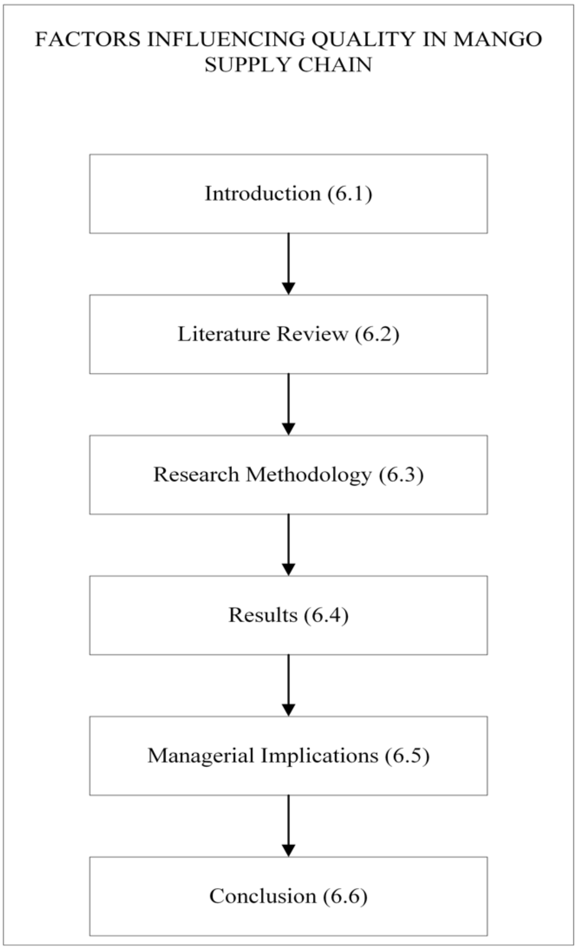


Figure 45 Overview of Chapter 6

6.1 Introduction

India is the world's leading producer of horticultural crops such as mangoes, bananas, papayas, cashews, areca nuts, potatoes, and okara (FAO, 2018). With a total mango production capacity of 24.7 million tonnes, India controls 45.14 percent of the market (FAO, 2020). Fruits and vegetables cultivated in gardens in India account for at least 90% of the country's agricultural output. Mango is widely grown in India in Uttar Pradesh, Andhra Pradesh, Telangana, Tamil Nadu, Karnataka, Maharashtra, Gujarat, and Bihar. In terms of mango production, Telangana ranks sixth in the country. Mangoes are grown on 128524 hectares, yielding 1.2 million tonnes (APEDA, 2021). The average quantity of mangoes produced per hectare in Telangana is 4.2 tonnes. Most of the state's mango output is attributable to the districts of Jagtial, Khammam, Nagarkurnool, Ranga Reddy, and Mancherial. Telangana cultivates commercially significant cultivars such as Banganapalli, Suvarnarekha, Neelum, and Totapuri. Mango orchards can be run by the farmer, a hired manager, or a pre-harvest contractor (who leases the orchard from the farmer). Pre-harvest contractors rent the orchards from the farmers on a contractual basis during the post-harvest period (undertake all the operations for the following harvest season on their own). Leasing the orchard is an option after flowering and again when the fruit is just beginning to set (R. Srihari Babu, 2015). All tasks in the mango orchard are handled by hired managers, farmers, or pre-harvest contractors, with the help of harvesting labor, during the harvest and pre-harvest periods. Fruit is sold directly to a post-harvest buyer (who pays a single price for the entire crop) or delivered to a collection center (i.e., mandi). Several commission agents or wholesalers hold parallel open auctions at the mandi. They also play the role between the farmer, the pre-harvest contractor, and the buyer (R. Srihari Babu, 2015).

Pruning is the removal of parts of the branches of the tree. Pruning results in a more uniform branch distribution within the mango tree and increases airflow. Sunlight is essential in the growth of mango fruit(Kumar et al., 2020a). Depending on the crop type and soil type, there is a vast array of possible irrigation strategies (Williamson and Crane, 2010). Mango trees can be irrigated using various methods, depending on the plantation. Throughout the year, mango trees are irrigated, except during the rainy season. Fertilizers boost production by delivering nutrients to the soil; the quantity produced can be affected by knowledge of the proper fertilizer when to apply the fertilizer, and the cost of the fertilizer (Azam et al., 2022). Pesticides help reduce the damage-causing insects and other pests on mango trees during the flowering season. The quantity created is affected by variables such as the kind of chemicals employed, the timing of pesticide application, and their cost (Muriithi et al., 2021). Figure 43 presents the conceptual model of this study. Soil preparation and pre- and post-sowing activities are separate from our study.

The harvesting practices include picking, desapping, and sorting. Mango post-harvest management is mainly determined by how the mangos are harvested. Whether or not mangoes are ready to be picked depends on how old they are, and the farmer decides to pick them early in the morning so that the mangoes do not get too much sun after they are picked (Gómez-Lagos et al., 2021). When a fruit is desapped, its stalk is removed after harvesting. Desapping removes sap from the stalk to reduce the risk of sap burns (Barman et al., 2015). Farmers typically use plastic crates to classify mangoes by size. Bamboo baskets and jute bags are also frequently used for transportation. Other farmers load the mangoes into the truck without sorting them. Mangoes can be stored in orchards or cold storage after harvest. Farmers can use the government's cold storage facilities at a low cost. Once mangoes are packaged, they are transported to the nearest mandi for sale. A commission agent or wholesaler holds an open auction at the mandi to facilitate the exchange of goods between the farmer and the buyer (R. Srihari Babu, 2015).

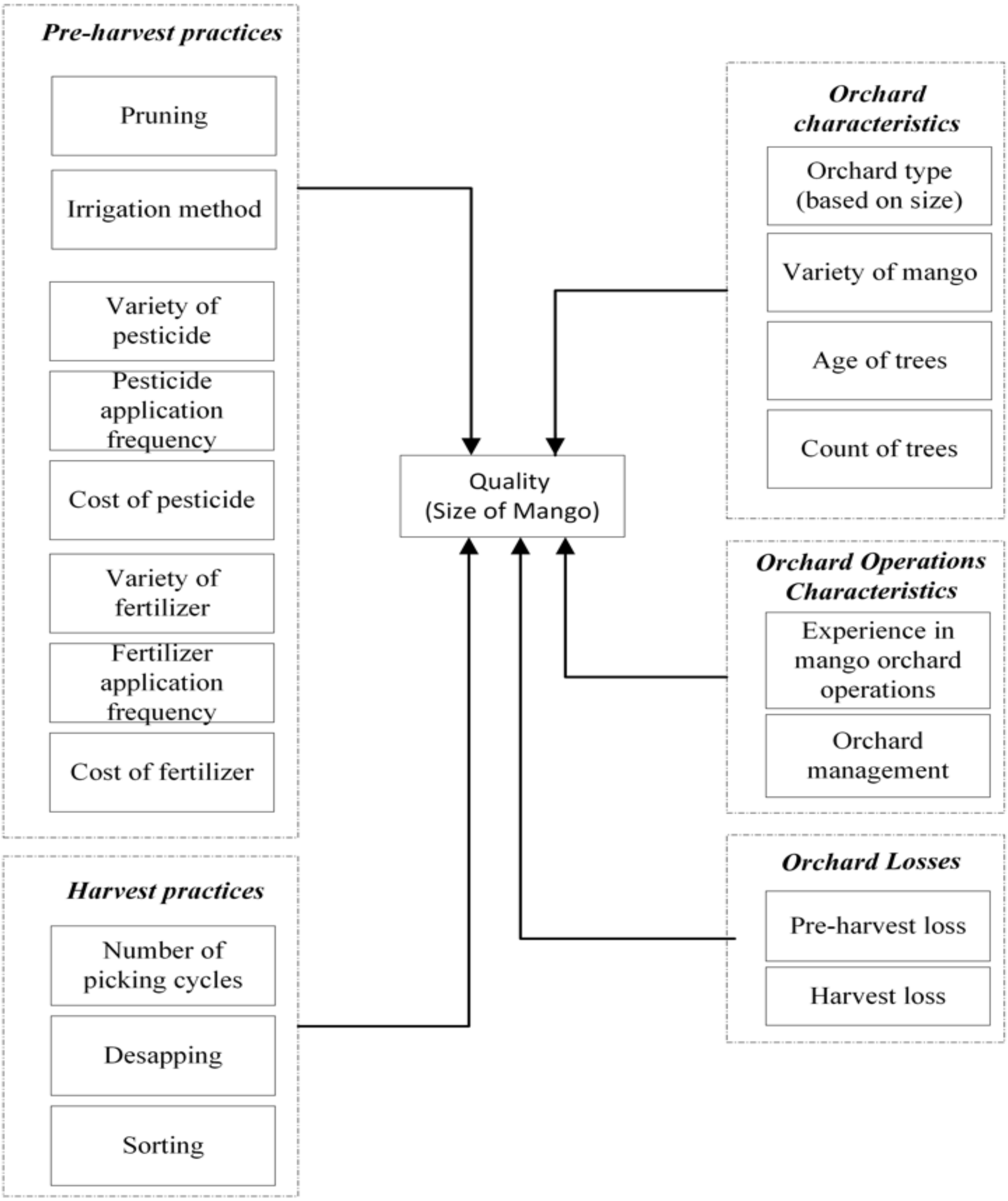


Figure 46 Conceptual Framework of Harvest Quality in the Mango Supply Chain

More studies have yet to be undertaken to establish the significance of harvest quality (size of mango). Harvest quality of mango is our study utilizes the size of the mango, which is the proxy for harvest quality at the mandi for determining the market rate. Our analysis is based on a survey of 240 respondents in Telangana, India, including farmers, hired managers, and pre-harvest contractors.

6.2 Literature Review

This literature review examines the full scope of activities carried out in mango orchards until mandi between harvests. This section has been broken down into four subsections for ease of reading: mango orchard losses, pre-harvest practices, and harvest practices. To get a better perspective, we examined the relevant literature from an operational, horticultural, and economic standpoint. Our findings also reveal several operational gaps in managing the mango supply chain.

6.2.1 Mango Orchard Losses

Over forty percent of the current normalized food loss rate for main agri-food products can be attributed to loss reduction chances, as stated by (Lu et al., 2022). Educating farmers on how to use contemporary harvesting and post-harvest technologies, boosting the usage of the cold chain, and educating consumers on the importance of eating healthily and getting adequate exercise are just a few of the essential things that can be done. Food waste and losses in soft fruit and vegetable production were investigated (Beausang, Hall, and Toma, 2017). According to the findings of this study, most farmers do not consider food waste a significant concern but rather something that must be embraced as a part of farming. Accurate yield estimates are difficult to achieve since farmers rarely record food loss. Causes of losses in the distribution of fruits and vegetables were identified by (Magalhães, Ferreira, and Silva, 2021). Transportation issues persist due to poor handling and operational performance, a lack of coordination, and a failure to share relevant information. The most critical elements for reducing post-harvest losses in India's fruit and vegetable supply chain were identified by (Gardas, Raut, and Narkhede, 2018). Some factors include an abundance of intermediaries in the marketing chain, a lack of processing facilities, links between farmers and processing units, and a need for relations between the farm and the market.

6.2.2 Pre-Harvest Practices

Because of pruning, mango trees benefit from increased airflow and a more even distribution of branches. In an experiment on 'Kent' mango orchards, (Kumar *et al.*, 2020a) experimented with two distinct tree-trimming methods. One method grows square-shaped trees to maximize the sunshine that reaches the fruit, while the other opens the canopy to expose as much fruit as possible to sunlight. Results from this study showed that exposure to sunlight encouraged the formation of red pigmentation in mango fruit without negatively impacting the fruit's quality.

Different irrigation methods are used for different soils, crops, and management philosophies (Williamson and Crane, 2010). A basin, furrow, drip, or spray system can irrigate a mango orchard. In a study conducted by (Schulze et al., 2013) at two commercial mango orchards where micro sprinklers were installed, full irrigation based on climatic water balance, deficit irrigation, and farmer-controlled scheduling were utilized. These results confirmed that deficit irrigation is an effective strategy for boosting agricultural water production and maintaining yield in dry periods. Complete irrigation systems, including micro-sprinklers, could increase farmers' earnings by as much as 55 percent. In research by Liu et al. (2021), Lipan et al. (2021), and Spreer et al. (2009), full irrigation was utilized throughout the growth phase, and regulated deficit irrigation was used during flowering, fruit enlargement and maturity to conserve irrigation water. The irrigation system supplied the plants with the required water; the inadequate irrigation levels used were 75%, 50%, and 33%. Mango size was reduced by regulated deficit watering without a commensurate drop in yield. Fruit yield increased by 10.1% in 2018 due to deficit irrigation at maturity, as did average fruit weight. Irrigation also affects mango yield (Zhang, Wang, and Li, 2019). Researchers conducted an orthogonal mango drip fertigation experiment between 2018 and 2019 to learn how irrigation volume and fertilizer regime affected mango yield, fruit quality, water use efficiency, and partial fertilizer output.

Sun et al. (2022) proposed 75% irrigation to boost water and fertilizer production, quality, and efficacy.

Utilizing fertilizers improves crop yields and the nutrient content of harvested goods. Azam et al. (2022) investigated the effects of nitrogen (N), phosphorus (P), and potassium (K) fertilizers on mango orchard vegetative and reproductive development, production, and fruit quality. Using NPK improved mango tree fruiting, yield, physiochemical properties, and quality. (de Mello Prado, 2010) They examined the development and nutrition of mango trees treated with phosphorus. Phosphorus levels in the soil went up after fertilization. However, this change only affected plant growth in the second growing season. Phosphorus treatment for three years resulted in a larger stem diameter without influencing fruit production.

Given that the severity of insect pests is strongly correlated with the production loss forecasted by farmers, pesticide use is crucial (van Mele, van Huis, and Thu Cuc, 2001). A report found that over 47% of 820 farmers who grew rice, sugarcane, beans, eggplant, potatoes, cabbage, and mango used too much pesticide. Misconceptions about pesticides and their use have far-reaching effects on people's knowledge, finances, farm ownership, chemical toxicity, crop composition, and locations (Dasgupta, Meisner, and Huq, 2007). Many different integrated pest management (IPM) tactics were tested on Kenyan mango farmers to see how they affected crop output, farmer income, pesticide application, and the environment's and the public's safety. Results showed that farmers that used integrated pest management had an increase in mango yields and net revenue, less pesticide use, and fewer negative health impacts. The economic, environmental, and health benefits of IPM expand significantly from a single approach to multiple methods (S. kifouly G. Midingoyi *et al.*, 2019). The familiarity of small farmers with mango pests and their willingness to accept IPM technology as a long-term strategy for controlling mango fruit flies was explored in Ethiopia. The most significant mango pest in the research area was the fruit fly. Mango production decreased by 28% due to fruit bugs (Muriithi *et al.*, 2021).

6.2.3 Harvest Practices

Harvesting mangoes entails a burst of high-intensity effort spread over a relatively short time (Gómez-Lagos *et al.*, 2021). The number of days after complete flowering determines the length of the harvesting season (Giuseppe Gianguzzi *et al.*, 2021). Customers showed the most interest in purchases made 126 to 133 days after full bloom. Chen and Chen (2021) use a stochastic programming model to optimize the expected cost of labor, storage space, shelf life, and transportation limitations throughout a harvest season. Picking is more labor-intensive in June than in July and August since farmers can only select mangoes when they are naturally ripe. (Escallón-Barrios *et al.*, 2022) developed an end-to-end analytics method that integrates data treatment, descriptive (simulation), and prescriptive (optimization) models to improve harvest operations in this agricultural system. The models accounted for strategic (harvest cycle), tactical (resource distribution), and operational considerations (transport allocation). Furthermore, thanks to their improved functional solutions, the regular harvest cycle has been reduced from 19.6 days to 8.3 days.

After being picked, mangoes must be desapped. Mangoes must have their stalks cut because sap from the stalk produces sap burn on the mango's skin, lowering the fruit's quality. Mangoes of the Chausa variety were subjected to desapping studies(Barman et al., 2015)—removal of stalks and then applying several chemical desapping solutions immediately. Following treatment, the fruit was left at room temperature (302 °C) for 12 days to air dry. Fruits treated with sodium hydroxide (1%) showed significantly less sap burn harm than the other treatments. This treatment increased the freshness of the fruit by reducing respiration and ethylene evolution rates.

6.2.4 Gaps in the Existing Literature

Mangoes are grown in India, accounting for about 45% of global production, but more research still needs to be done on what factors influence mango harvest quality at the mandi. Our research will inform farmers about what drives up or down mango yields. However, a better global supply of mangoes requires more research into boosting the number of mangoes produced in orchards.

6.3 Research Methodology

We adopted a quantitative approach and conducted a face-to-face survey utilizing a structured questionnaire as the research instrument for this study. During the first phase, semi-structured interviews were conducted with experts, including mango producers, wholesalers, market officials, and district horticulture officials, to determine the effects and possible implications on the harvest quality of mangoes. These interviews validated the applicability of the conceptual model. We created a structured questionnaire based on a review of existing literature and discussions with subject matter experts. In the questionnaire, respondents were required to provide their personal information, followed by questions about mango orchard operations characteristics, orchard characteristics, losses, pre-harvest practices, and harvest practices for 2021. First, we created an English version of the survey. Because the respondents were from Telangana and spoke the regional language Telugu, the questionnaire was translated entirely into Telugu for readability. The questionnaire consisted of 65 questions, which respondents answered in 25 to 30 minutes.

The sampling frame was the mango orchards in Telangana. We studied in Telangana, India's Jangaon, Rangareddy, and Yadadri Bhuvanagiri districts. We purposively selected these districts as the majority of the mangoes grown are transported to one collection center (mandi), making it more accessible in comparison to the responses received. We requested the sampling list from the district horticultural offices. Therefore, the mango orchard data were considered representative of this study. A total of 17612 mango orchards are present in the three districts.

The Design of Experiments (DOE) method helps identify factors enhancing mango harvest quality by investigating the characteristics and levels at which they function. We have considered the 19 factors represented in the conceptual model through a literature review and expert discussions. However, the acquired data revealed that we had to exclude nine factors due to low inter-respondent variability. We analyzed the data on ten factors, including a variety of mango, age, count of trees, experience in orchard operations, orchard management, variety of fertilizers, cost of fertilizer, variety of pesticides, pesticide application frequency, and the number of picking cycles.

6.4 Results

6.4.1 Multiple Regression Model on Mango Harvest Quality

We used multiple regression to identify the factors influencing mango harvest quality. Mango sorting by size was used as a proxy for mango harvest quality in the studies, and respondents who did not sort the harvested mangoes were excluded from the analysis. At the open auction at the mandi, the price paid to farmers and pre-harvest contractors is based on the medium to large mangoes ratio. Table 16 provides an overview of the harvest quality regression model. The R-square value suggests that independent variables explain 20.5 percent of the variance in mango harvest quality. The difference between the R-square and the adjusted R-square is 0.027, and the error component (ε) is displayed in the final column. ANOVA helps validate fourteen independent variables (Table 17). The p-value is less than 0.05 (0.00), suggesting the results are significant. The test explains variable validity (Table 17). Table 18 displays the findings of this analysis, which show that six factors significantly affected the harvest quality of the mangoes. The Variance Inflation Factor (VIF) results show no extreme multicollinearity, with all values between 1 and 2.

Table 18 Model Summary of Harvest Quality

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.453	.205	.178	.10669

Table 19 ANOVA Test on the Model of Harvest Quality

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.680	8	.085	7.467	.000
	Residual	2.629	231	.011		
	Total	3.309	239			

Table 20 Summary of the Regression on the Model of Harvest Quality of Mango

Model	Unstandardized Coefficients		t	Sig.	Collinearity Statistics	
	B	Std. Error			Tolerance	VIF
(Constant)	.645	.041	15.816	.000		
District- Jangaon	-.032	.016	-1.966	.050	.766	1.306
Variety of Fertilizer	-.018	.007	-2.759	.006	.826	1.211
Cost of Fertilizer	1.230E-6	.000	3.416	.001	.528	1.894
Variety of Pesticide	-.037	.012	-2.999	.003	.873	1.145
Pesticide Application Frequency	.770	.167	4.611	.000	.728	1.374

Number of Picking Cycles	-.047	.016	-2.876	.004	.698	1.433

6.4.2 Design of Experiments

The design of experiments employs historical minimum and maximum values for essential input variables and factor levels (D.C. Montgomery, 2013). The regression results serve as the foundation for the DOE model (Figure 44). Table 44 shows the levels evaluated for the model.

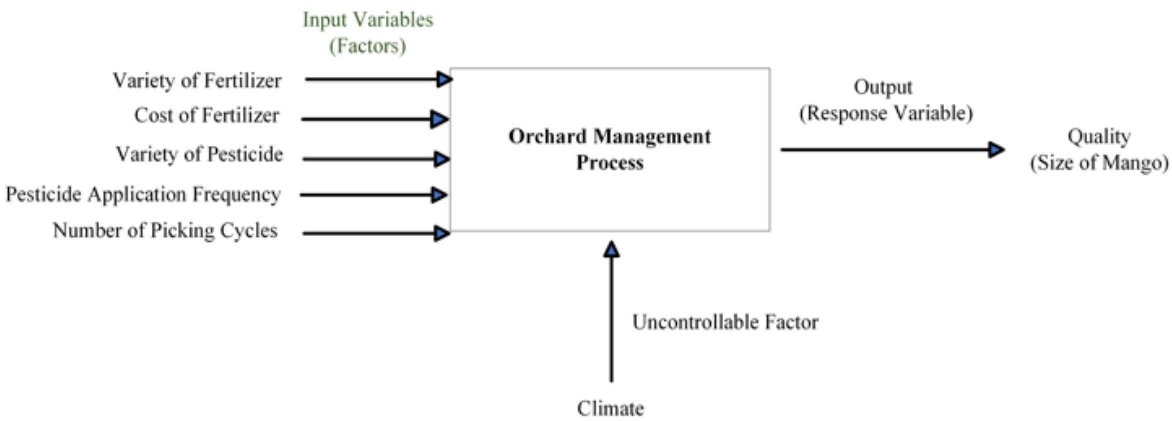


Figure 47 Orchard Management Model: Harvest Quality of Mango

Table 21 Input Variables for the Model – Harvest Quality (Response Variable)

Input Variables	Levels					
	1	2	3	4	5	6
Variety of Fertilizer	1	2	3	4	5	6
Cost of Fertilizer	Below 50000 INR	50000 to 100000 INR	Above 100000 INR			
Variety of Pesticide	1	2	3			
Pesticide Application Frequency	1	2	3	4		
Number of Picking Cycles	1	2	3			

The main factor effect and interaction effect on the response variable are understood using DOE (D.C. Montgomery, 2013b). A summary of the DOE model's consequences is shown in Figure 48.

The main factor effects that are significant impact on harvest quality are : Variety of fertilizer, Variety of pesticides, Pesticide application frequency, Cost of fertilizer, Number of picking cycles.

Interaction factor effects that are significant impact on harvest quality are: Cost of fertilizer and pesticide application frequency, Number of picking cycles and cost of fertilizer, Variety of fertilizer and pesticide application frequency, Variety of pesticide and pesticide application frequency, Cost of fertilizer and variety of fertilizer, Cost of fertilizer and variety of pesticide, Number of picking cycles and variety of fertilizer, Number of picking cycles and variety of pesticide, Number of picking cycles and pesticide application frequency.

Source	Logworth	PValue
Pesticide Application Frequency*Cost of Fertilizer	24.529	0.00000
Number of Picking Cycle*Cost of Fertilizer	19.563	0.00000
Variety of Fertilizer*Variety of Pesticide	17.959	0.00000
Variety of Pesticide(1,6)	17.613	0.00000 ^
Variety of Fertilizer(1,6)	17.136	0.00000 ^
Variety of Fertilizer*Pesticide Application Frequency	17.092	0.00000
Pesticide Application Frequency	15.379	0.00000 ^
Variety of Pesticide*Pesticide Application Frequency	15.307	0.00000
Variety of Fertilizer*Cost of Fertilizer	12.837	0.00000
Variety of Pesticide*Cost of Fertilizer	12.109	0.00000
Cost of Fertilizer	11.061	0.00000 ^
Variety of Fertilizer*Number of Picking Cycle	10.824	0.00000
Variety of Pesticide*Number of Picking Cycle	10.726	0.00000
Number of Picking Cycle	10.494	0.00000 ^
Number of Picking Cycle*Pesticide Application Frequency	9.218	0.00000

Figure 48 Effects Summary: Design of Experiment for Harvest Quality

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	40	2896.0419	72.4010	78.5798
Error	159	146.4979	0.9214	**Prob > F**
C. Total	199	3042.5398		<.0001*

Figure 49 Analysis of Variance for Harvest Quality

Figure 49 shows the variance analysis and DOE done on mango orchard harvest quality. The overall significance of the DOE model is suggested by the model's F value, which is less than 0.05. The model (higher value of the model sum of squares) explains a sizeable portion of the observed variation. The parameter estimations are shown in Figure 50, with a p-value of less than 0.05. The findings about their impact on harvest quality and the inference made from this data are statistically significant, according to prior observations. We deduce from parameter estimations that the quality of the harvest is influenced by a number of variables and their interactions.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Variety of Fertilizer(1,6)	0.9979797	0.102582	9.73	<.0001*
Variety of Pesticide(1,6)	1.0183147	0.102796	9.91	<.0001*
Number of Picking Cycle[1]	0.9061541	0.14557	6.22	<.0001*
Number of Picking Cycle[2]	-0.973363	0.144459	-6.74	<.0001*
Pesticide Application Frequency[1]	0.9543514	0.177852	5.37	<.0001*
Pesticide Application Frequency[2]	-1.149368	0.177852	-6.46	<.0001*
Pesticide Application Frequency[3]	1.0332547	0.177852	5.81	<.0001*
Cost of Fertilizer[Below 50000]	0.94755	0.14557	6.51	<.0001*
Cost of Fertilizer[50000 to 100000]	-0.992863	0.144459	-6.87	<.0001*
Variety of Fertilizer*Variety of Pesticide	1.0305087	0.102698	10.03	<.0001*
Variety of Fertilizer*Number of Picking Cycle[1]	0.9444986	0.145923	6.47	<.0001*
Variety of Fertilizer*Number of Picking Cycle[2]	-0.976454	0.144724	-6.75	<.0001*
Variety of Fertilizer*Pesticide Application Frequency[1]	1.1560254	0.178041	6.49	<.0001*
Variety of Fertilizer*Pesticide Application Frequency[2]	-1.085473	0.178041	-6.10	<.0001*
Variety of Fertilizer*Pesticide Application Frequency[3]	0.974814	0.178041	5.48	<.0001*
Variety of Fertilizer*Cost of Fertilizer[Below 50000]	1.1097267	0.145923	7.60	<.0001*
Variety of Fertilizer*Cost of Fertilizer[50000 to 100000]	-1.010612	0.144724	-6.98	<.0001*
Variety of Pesticide*Number of Picking Cycle[1]	0.956652	0.14607	6.55	<.0001*
Variety of Pesticide*Number of Picking Cycle[2]	-0.957359	0.144876	-6.61	<.0001*
Variety of Pesticide*Pesticide Application Frequency[1]	0.9655097	0.177958	5.43	<.0001*
Variety of Pesticide*Pesticide Application Frequency[2]	-1.15714	0.177958	-6.50	<.0001*
Variety of Pesticide*Pesticide Application Frequency[3]	1.0126868	0.177958	5.69	<.0001*
Variety of Pesticide*Cost of Fertilizer[Below 50000]	0.9580558	0.14607	6.56	<.0001*

Term	Estimate	Std Error	t Ratio	Prob>|t|
Variety of Pesticide*Cost of Fertilizer[50000 to 100000]	-1.083681	0.144876	-7.48	<.0001*
Number of Picking Cycle[1]*Pesticide Application Frequency[1]	0.7845627	0.253983	3.09	0.0024*
Number of Picking Cycle[1]*Pesticide Application Frequency[2]	-0.950689	0.253749	-3.75	0.0002*
Number of Picking Cycle[1]*Pesticide Application Frequency[3]	0.8939852	0.253983	3.52	0.0006*
Number of Picking Cycle[2]*Pesticide Application Frequency[1]	-1.069312	0.247574	-4.32	<.0001*
Number of Picking Cycle[2]*Pesticide Application Frequency[2]	1.2102831	0.253294	4.78	<.0001*
Number of Picking Cycle[2]*Pesticide Application Frequency[3]	-1.137299	0.247574	-4.59	<.0001*
Number of Picking Cycle[1]*Cost of Fertilizer[Below 50000]	1.0903312	0.207113	5.26	<.0001*
Number of Picking Cycle[1]*Cost of Fertilizer[50000 to 100000]	-1.117709	0.206096	-5.42	<.0001*
Number of Picking Cycle[2]*Cost of Fertilizer[Below 50000]	0.9091476	0.206096	4.41	<.0001*
Number of Picking Cycle[2]*Cost of Fertilizer[50000 to 100000]	-1.011487	0.20221	-5.00	<.0001*
Pesticide Application Frequency[1]*Cost of Fertilizer[Below 50000]	1.100042	0.248159	4.43	<.0001*
Pesticide Application Frequency[1]*Cost of Fertilizer[50000 to 100000]	-1.022307	0.253294	-4.04	<.0001*
Pesticide Application Frequency[2]*Cost of Fertilizer[Below 50000]	1.1608503	0.253983	4.57	<.0001*
Pesticide Application Frequency[2]*Cost of Fertilizer[50000 to 100000]	-0.959146	0.247574	-3.87	0.0002*
Pesticide Application Frequency[3]*Cost of Fertilizer[Below 50000]	0.7569493	0.253749	2.98	0.0033*
Pesticide Application Frequency[3]*Cost of Fertilizer[50000 to 100000]	-0.988514	0.253294	-3.90	0.0001*

Figure 50 Parameter Estimates for Harvest Quality

Figure 44 shows the Prediction Profiler, which enables you to interactively assess the effects on your response variable when you alter the settings for a single factor while maintaining the values for the other factors (D.C. Montgomery, 2013b). In Figure 51, the factors are on the X-axis and the response variable (harvest quality) is on the Y-axis. The vertical red line in the prediction (Figure 51) shows the optimal amount at six different fertilisers, six different pesticides, one picking cycle, and one pesticide application frequency.

The function of desirability is rated on a scale of 0 to 1, with 1 being the most desirable result. The function of desirability is employed to evaluate the model's suitability for data conformity and outcome prediction. The pre-harvest loss model developed in this scenario received a desirability score of 0.999, indicating that it is very desirably (D.C. Montgomery, 2013b).

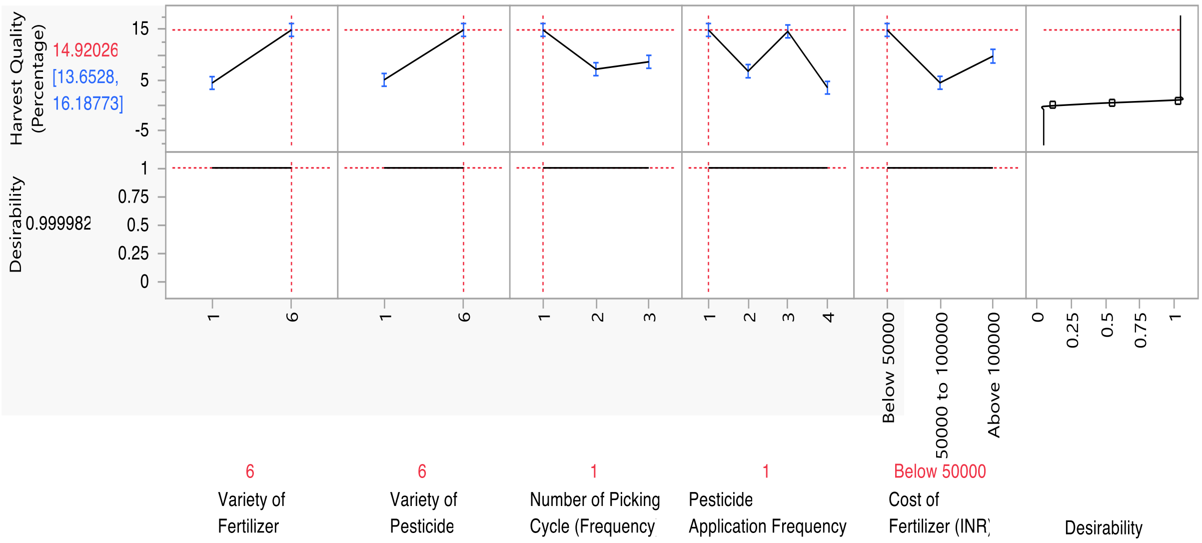


Figure 51 Prediction Profiler for Harvest Quality

6.5 Managerial Implications

After conducting a study on the factors influencing harvest quality (size of mango), guidance and implications to marginal and small orchard farmers is provided to improve harvest quality (Table 22).

Table 22 Guidance to Marginal and Small Orchard Farmers

Factors	Guidance to Marginal and Small Orchard Farmers
Variety of Fertilizer	Usage of six varieties based on the requirement
Variety of Pesticides	Usage of six varieties based on the requirement
Number of Picking Cycles	One picking cycle in a year
Pesticide Application Frequency	Once a year based on the requirement
Cost of Fertilizer	Investing at least 50000 INR on orchard in required

Our findings indicate that the variety of fertilizer and the cost of fertilizer impact the harvest quality of mangoes. We reached out to the farmers to confirm our findings. Increasing the number of fertilizers used according to the need helps improve the harvest quality of mangoes.

Results suggest that using more fertilizers varieties applied, optimally six varieties based on the requirement will help improve the harvest quality.

Harvest losses were significantly influenced by the frequency of pesticide applications. According to conversations with experts, spraying pesticides before and during the blossoming time minimises infestations and insects. Furthermore, producers claim that older trees need more pesticides than younger plants. Farmers will be able to understand the relevance of planning pesticide applications to avoid harvest losses thanks to this research. Once a year pesticide applications serve to increase the quality of the harvest.

The findings show that the number of picking cycles affects mango harvest quality (size). Picking cycles ranged from one to three, according to survey results. Considering the findings, we contacted the farmers for clarification, and they agreed that the picking cycles should be increased to improve the harvest quality (size of mango). According findings two picking cycles in a year will help improve harvest quality..

There is a significant relationship among factor interactions such as the variety of fertilizer and pesticide application frequency, the variety of fertilizer and the number of picking cycles, variety of fertilizer and variety of pesticide, variety of fertilizer and cost of fertilizer, cost of fertilizer and pesticide application frequency, cost of fertilizer and the number of picking cycles, cost of fertilizer and variety of pesticide, variety of pesticide and number of picking cycles, variety of pesticide and pesticide application frequency, and pesticide application frequency and the number of picking cycles.

6.6 Conclusion

In India, mango is one of the most widely produced fruits. The operations of mango orchards significantly impact fruit harvest quality and supply chain losses. Literature indicates a necessity for in-depth analysis of harvest quality during harvesting stages. This research investigates the factors that affect mango harvest quality, specifically in mango orchards. Based on the findings of our literature review and in-depth interviews with horticultural experts, we constructed a conceptual model with 19 factors. The research's third objective is to investigate the factors impacting the harvest quality (size of mango) of mangoes in the supply chain and suggest recommendations to farmers to enhance the harvest quality. This chapter achieves its objective by defining important factors and offering advice to both orchard managers and small producers.

We created a standardized questionnaire while conducting face-to-face interviews with farmers, pre-harvest contractors, and hired managers. The total number of responses we got was 240. SPSS v26 was utilized for data analysis in this study. We used data cleansing, feature engineering, and multiple regression to comprehend the harvest quality of mangoes in the mango garden. The significance of each factor's effect on harvest quality and degree of interaction between components is significant from the design of experiments. We have chosen the factors that influence the harvest quality, which include the number of picking cycles, the cost of fertilizer, the variety of fertilizers used, the variety of pesticides used, and pesticide application frequency. Future research could focus on pre-harvest and harvest fruit losses. More research on type farmers is possible, as is raising awareness of small and marginal farmers. A mango supply chain sustainability analysis is necessary. Furthermore, research on mango production control, other fruits, and technological applications is required.

7 CHAPTER: FACTORS INFLUENCING HARVEST QUANTITY IN MANGO SUPPLY CHAIN

This chapter overviews the factors influencing harvest quantity in the mango supply chain. The chapter is divided into six sections. The first section provides an introduction to this chapter. Next, a literature review is presented on pre-harvest practices, harvest practices, and losses in the mango supply chain. The research methodology for this study is provided in the following section. Following that, the study's results are provided using multiple regression and the design of experiments. Finally, managerial implications and concluding remarks in this chapter are presented. Figure 48 depicts a visual overview of this chapter.

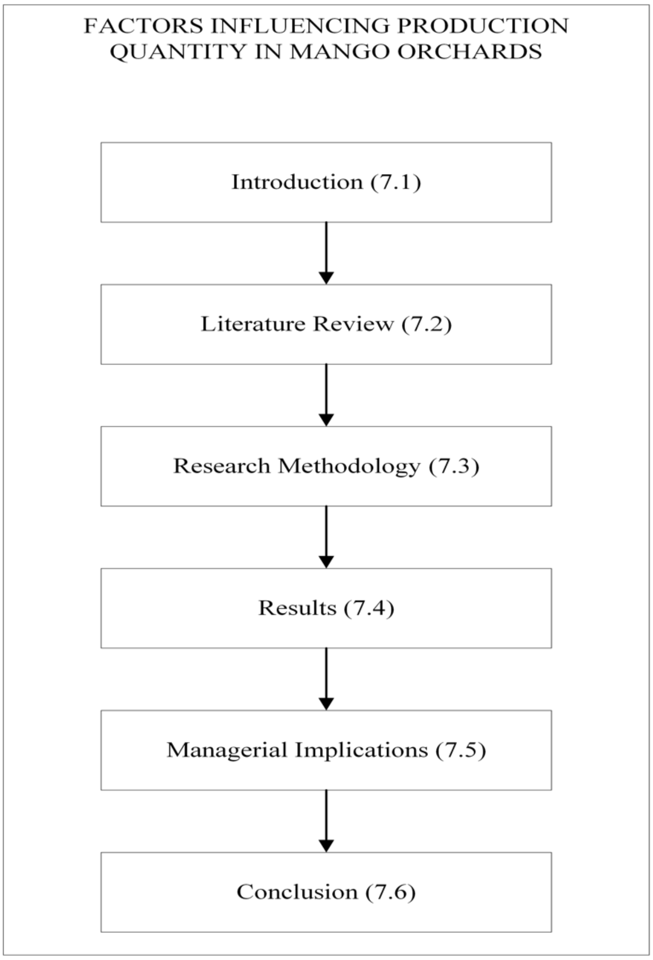


Figure 52 Overview of Chapter 7

7.1 Introduction

The Food and Agriculture Organization defines horticulture as plant agriculture focusing on garden crops, fruits, vegetables, and ornamental plants. This name is derived from the Latin words hortus and colere, which indicate "garden" and "to cultivate." India is the largest producer of various horticultural crops, including mango, banana, papaya, cashew nut, areca nut, potato, and okara (FAO, 2018). India holds a 45.14 percent market share with a harvest quantity of 24.7 million tonnes (FAO, 2020). Ninety percent or more of India's horticultural output comprises fruits and vegetables. In India, mango is cultivated abundantly in Uttar Pradesh, Andhra Pradesh, Telangana, Tamil Nadu, Karnataka, Maharashtra, Gujarat, and Bihar. Telangana is sixth in the nation for mango production. Telangana has a total of 33 districts. Mango is cultivated on 128524 hectares with a harvest quantity of 1270364 metric tonnes (APEDA, 2021). Telangana's average mango harvest quantity per hectare is 4.2 metric tonnes. Jagtial, Khammam, Nagarkurnool, Ranga Reddy, and Mancherial are the most significant mango-producing districts. Telangana cultivates Banganapalli, Suvarnarekha, Neelum, and Totapuri as commercial varieties.

The farmer manages Mango orchards (who owns the orchard), hired managers (who work for the orchard owner), or pre-harvest contractors (who lease the orchard from the farmer). Pre-harvest contractors lease the farmers' orchards during the post-harvest season under the contract conditions (undertake all the operations for the following harvest season on their own). Alternatively, lease the orchard after the blooming season or during the early fruit set stage (R. Srihari Babu, 2015). During pre-harvest and harvest season, hired managers, farmers, or pre-harvest contractors undertake all activities in the mango orchard with the assistance of additional harvesting labor. Farmers either sell their product directly to a post-harvest buyer (who offers a lump sum payment and purchases the whole crop) or deliver their produce to the nearest collection center (i.e., mandi). Multiple commission agents or wholesalers at the mandi conduct parallel open auctions and mediate between the farmer, the pre-harvest contractor, and the buyer (R. Srihari Babu, 2015).

Pruning removes a portion of a tree's branches to produce a more uniform branch distribution and improve ventilation within the mango tree. The growth of mango fruit aids by exposure to sunlight (S. P. Kumar et al., 2020). Depending on the crop type and soil, irrigation methods vary widely(Williamson and Crane, 2010). Mango trees are irrigated year-round, except for the rainy season, and the irrigation method varies amongst orchards. Fertilizers boost output by adding nutrients to the soil; understanding the correct fertilizer, when to apply it, and the fertilizer cost may influence the quantity produced (Azam et al., 2022). During the flowering season of mango trees, pesticides suppress pests that might damage the fruit. The appropriate chemicals, the timing of pesticide application, and the cost of pesticides impact the quantity produced (Muriithi et al., 2021). Our study confines operations in mango plantations between harvest seasons. Other pre-harvest procedures have yet to be included, including soil preparation, pre-sowing, and post-sowing.

Picking, desapping, and sorting are harvesting procedures. Mango post-harvest management is determined mainly by the harvesting procedure. Mangoes are harvested based on their level of ripeness, and the farmer chooses to harvest them early in the morning to minimize their exposure to sunlight after harvesting (Gómez-Lagos et al., 2021). Desapping is the process of removing the fruit's stalk after harvesting. Desapping removes sap from the stalk, preventing sap burns (Barman et al., 2015). Mangoes are sorted based on size small, medium, and large. Packaging materials include plastic crates, jute bags, and bamboo baskets. Few farmers also load all mangoes directly into the truck without sorting. Mangoes are stored in orchards or refrigerated storage facilities after harvest. Farmers can utilize cold storage facilities controlled by the government for a very minimal price. Mangoes are taken to the nearest mandi for sale after being packaged. A commission agent or wholesaler works as an intermediary between the farmer and the buyer by selling the produce fairly at the mandi's open auction (R. Srihari Babu, 2015). Figure 49 depicts the conceptual framework to understand the impact of pre-harvest practices, harvest practices, orchard characteristics, orchard operations characteristics, and losses on the harvest quantity.

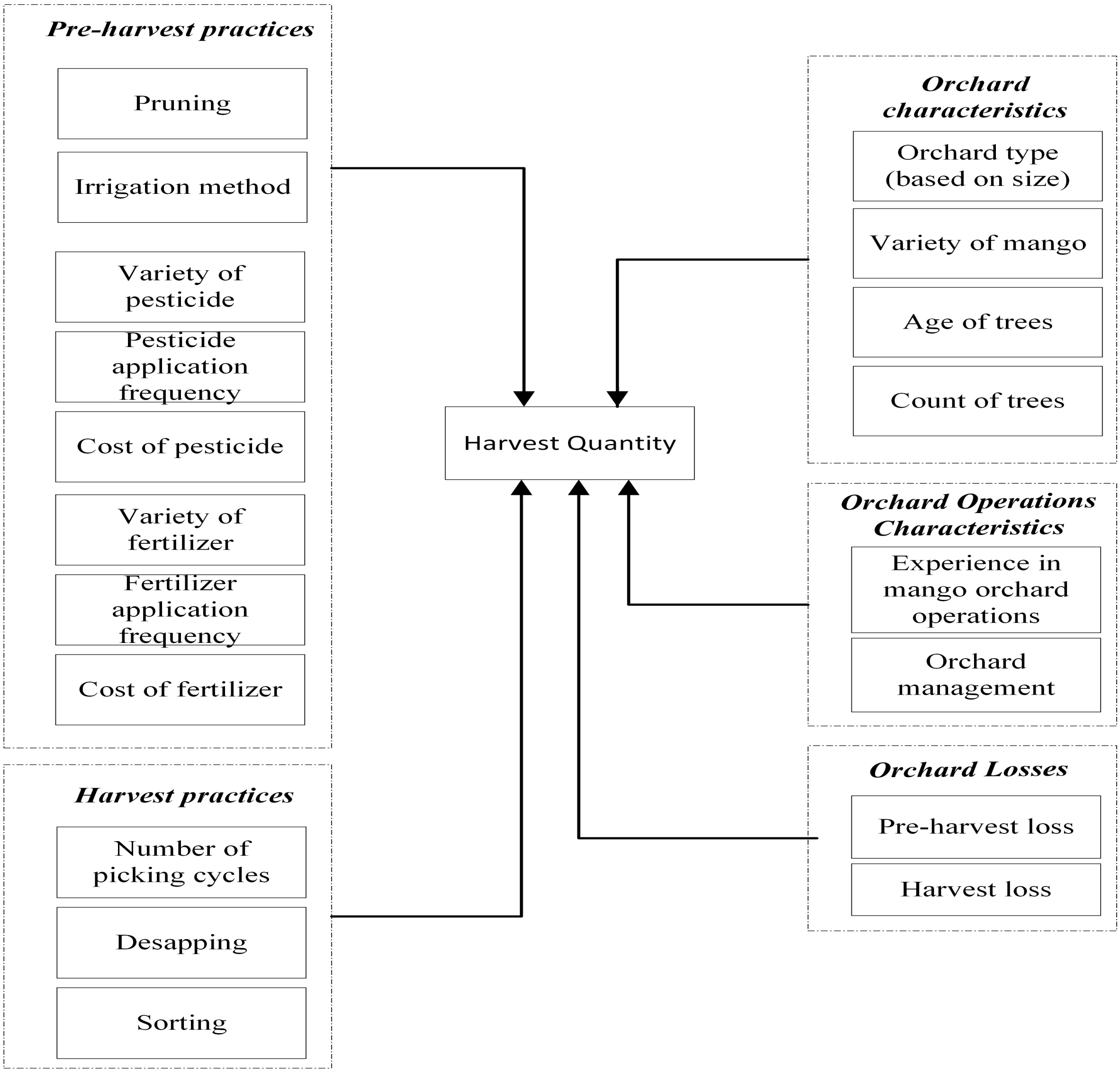


Figure 53 Conceptual Framework of Harvest Quantity in the Mango Supply Chain

7.2 Literature Review

This section of the literature focuses on all practices in mango orchards till mandi from one harvest to another harvest cycle. For better understanding, we divided this section into four sub-sections: losses in mango orchards (7.2.1), pre-harvest practices (7.2.2), and harvest practices (7.2.3). We reviewed literature from the operational, horticultural, and economic perspectives to understand better. Our research also highlights the gaps in the mango orchard practices from an operations perspective, as shown in sub-section 7.2.4.

7.2.1 Losses in Mango Orchards

According to Lu et al. (2022), there is an ample opportunity for loss reduction in the food supply chain, with more than 40 percent of the present normalized food loss rate for major agri-food items attributable to loss reduction opportunities. Essential mitigating techniques that should pursue include training farmers in contemporary harvesting and post-harvest technology, boosting cold chain utilization, and educating consumers about nutrition and health. Beausang, Hall, and Toma (2017) investigated farmers' perspectives on food waste and losses in soft fruit and vegetable fields. This study indicated that farmers do not view food waste as a significant worry but as an inherent aspect of agriculture. Farmers have trouble giving estimates of food waste and losses because they do not frequently record waste.

Magalhães, Ferreira, and Silva (2021) found causes for fruit and vegetable supply chain losses. Causes include insufficient transportation infrastructure, inadequate or faulty packing and storage facilities, poor handling and operating performance, and a lack of coordination and information exchange. Gardas, Raut, and Narkhede (2018) found the most critical factors that must address to ensure a progressive reduction in post-harvest losses in India's fruit and vegetable supply chain. Factors are lack of proper packaging and storage facilities, lack of adequate infrastructure, better handling of the products on the farm and in the market, lack of processing facilities, lack of links between farmers and processing units, lack of links in the marketing chain, and many intermediaries.

7.2.2 Pre-Harvest Practices

Pruning removes a section of a tree's branches to establish a more uniform branch distribution and enhance the mango tree's ventilation. S. P. Kumar et al. (2020) experimented on' Kent' mango orchards using two pruning procedures. One method opens the canopy to expose as much fruit as possible to sunshine, while the other generates square-shaped trees and lowers the quantity of sunlight that reaches the fruit. This study gave proof of the favorable effects of sunshine on the development of red pigmentation in mango fruit without impairing its harvest quality.

Irrigation techniques vary considerably depending on soil type, crop, and management philosophy (Williamson and Crane, 2010). In a mango orchard, basin, furrow, drip, or spray irrigation systems may use. Schulze et al. (2013) conducted research in which micro sprinklers were installed in two commercial mango plantations using full irrigation based on climatic water balance, deficit irrigation, and farmer-controlled scheduling. The findings demonstrated that deficit irrigation increases agricultural water production and stabilizes yield during drought. Farmers may increase their profits by 55% with complete irrigation and micro-sprinklers. Liu et al. (2021), Lipan et al. (2021), and Spreer et al. (2009) employed four irrigation levels to conserve irrigation water, including full irrigation throughout the growth phase and managed deficit irrigation during blooming, fruit enlargement, and maturity. Full irrigation satisfied all the crop's water needs: seventy-five percent, fifty percent, and thirty-three percent were allocated to deficiency irrigation levels. The results showed that managed deficit irrigation reduced mango size without affecting yield. In 2018, fruit yield increased by 10.1% due to deficit irrigation at maturity, while the average fruit weight increased. Irrigation timing also influences mango production (Zhang et al., 2019). An orthogonal mango drip fertigation experiment was conducted in 2018–2019 to determine how irrigation amount and fertilizer regime influenced mango harvest quantity, fruit quality, water consumption efficiency, and partial fertilizer productivity. Sun et al. (2022) recommended Seventy-five percent irrigation to enhance yield, quality, and water–fertilizer efficiency.

Fertilizer usage influences crop productivity and fruit quality. Azam et al. (2022) examined the effects of nitrogen (N), phosphorus (P), and potassium (K) fertilizers on mango orchard vegetative and reproductive development, yield, and fruit quality. NPK increased mango trees' fruiting, yield, physiochemical characteristics, and fruit quality. After treating mango trees with phosphorus, De Mello Prado (2010) analyzed their nutrition and growth. Using fertilizer increased phosphorus levels in the soil but only altered plant performance in the second year. Phosphorus increased the diameter of the plant's stem after three years of treatment but did not affect the fruit set.

Pesticide application is vital since farmers' predicted production loss due to insect pests is directly proportional to pest severity (van Mele, van Huis, and Thu Cuc, 2001). Over 47% of 820 rice, sugarcane, bean, eggplant, potato, cabbage, and mango farmers in Bangladesh utilized excessive levels of pesticide, according to a report. Pesticide misuse significantly impacts misunderstanding, income, farm ownership, chemical toxicity, crop mixture, and geography (Dasgupta, Meisner, and Huq, 2007). The impacts of a range of integrated pest management (IPM) strategies on mango yield, net income, pesticide use, human health, and the environment were studied by Kenyan mango producers. According to the research, farmers that utilize integrated pest control have greater mango yields and net revenue, use less pesticide and cause less harm to the environment and human health. In addition, shifting from one IPM strategy to several IPM techniques generates broader economic, environmental, and health advantages (S. kifouly G. Midingoyi *et al.*, 2019). Examined in Ethiopia were the knowledge, beliefs, and actions of small farmers regarding mango pests, as well as their intention to employ IPM technology as a sustainable technique for mango fruit fly management. The fruit fly was the research region's most economically significant mango pest. Fruit flies contributed to 28% of mango output declines (Muriithi *et al.*, 2021).

7.2.3 Harvest Practices

Mango picking involves plucking the fruit off the trees, which requires a brief period of intense work (Gómez-Lagos et al., 2021). According to Gianguzzi et al. (2021), the harvesting season's duration depends on the days following full flowering and harvesting between 126 and 133 days after full bloom was optimal for customer acceptance. Chen and Chen (2021) utilized a stochastic programming model to study the decisions of picking during a harvesting season to optimize the expected cost of labor, storage space, shelf life, and transportation limitations. Mango harvesting is more labor-intensive than in July and August because growers can only harvest naturally ripe mangoes in June. A study by Escallón-Barrios et al. (2022) offered an end-to-end analytics method consisting of data treatment, descriptive (simulation), and prescriptive (optimization) models to improve harvest activities in this agricultural system. The models comprised strategic (harvest cycle), tactical (resource distribution), and operational decisions (transport allocation). In addition, they have created operational solutions that reduce the average harvest cycle time from 19.6 to 8.3 days.

Mangoes are desapped after picking. Mangoes are de-stemmed; sap pours from the stem create sap burn on the mango's outer layer, diminishing the fruit's quality. Barman et al. (2015) investigated desapping on the Chausa type of mango; fruits were de-stemmed and immediately treated with multiple desapping chemical solutions. The fruits were air-dried and kept at room temperature (30±2 °C) for 12 days after treatment. Compared to the other treatments, fruits with sodium hydroxide (1%) exhibited much-reduced sap burn injury. This treatment enhanced the fruit's shelf life by reducing ripening through reduced respiration and ethylene evolution rates.

7.2.4 Gaps in the Existing Literature

India accounts for nearly 45 percent of the world's mango production; however, research on factors influencing the quantity and harvest quality of mangoes in the Indian context is minimal. Our study will help the farmers identify the factors affecting mango harvest quantity. There have been studies on increasing the shelf-life of mangoes for export purposes. However, more studies on increasing the harvest quantity of mangoes at the orchard level are essential as they will improve the supply of mangoes across the globe.

7.3 Research Methodology

To examine the effects of various factors on harvest quantity, we follow the Design of Experiments (DOE) methodology to develop an experimental design showcasing the individual and interaction effects of the significant factors (D.C. Montgomery, 2013b). We reviewed the literature to establish the research questions, extract factors, and contact mango orchard farmers. Developed a structured questionnaire, received responses from farmers/hired managers/pre-harvest contractors, and collected data via a face-to-face survey. We considered significant factors for developing an experimental design from the regression results. We gathered the population data of mango farmers in all three districts. We visited the horticulture offices of each of these districts to gather this data. From the data gathered, based on the orchard acreage, we categorized them into marginal, small, semi-medium, and medium (Ministry of Agriculture & Farmers Welfare, 2019).

Most orchards (80 percent) fall under marginal, followed by small (12 percent). For this study, we employed a stratified sampling technique in which the four orchard sizes (marginal, small, semi-medium, and medium) each represent a separate stratum. A total of 332 farmers/hired managers/pre-harvest contractors) were surveyed for the study, with about 110 from each district participating.

7.4 Results

The collected data from the respondents were analyzed using version 26 of Statistical Processing for Social Science (SPSS). We conducted a multiple linear regression to determine the significant factors influencing mango harvest quantity (4.1). The sample comprises marginal, small, semi-medium, and medium orchard types. As the percentage of medium orchard types representing the sample is only 9 percent (30 responses), we have excluded these responses from our analysis. Out of 332 responses collected, we used 301 to analyze the harvest quantity. Utilizing the design of experiments (DOE) method, we determined how input factors affect harvest quantity (4.2). We utilized JMP software to run the experimental design.

7.4.1 Multiple Regression Model on Harvest Quantity

We performed a multiple regression to identify the factors impacting harvest quantity. We considered fifteen factors for this model: Pre-harvest loss, harvest loss, orchard management, experience in orchard operations, orchard type, variety of mango count of trees, the weighted average age of trees, district, variety of fertilizer, cost of fertilizer application, variety of pesticide, pesticide application frequency, number of picking cycles and sorting. However, we eliminated the cost of pesticide application due to its high correlation with the fertilizer application cost. Also, we eliminated factors representing pruning, irrigation method, fertilizer application frequency, and desapping, as the responses demonstrated no significant difference.

Table 20 presents the summary of the regression model on harvest quantity. The R-square value indicates that independent variables can explain 42.3 percent of the variance in the productivity of mangoes. The difference between the R-square and adjusted R-square is 0.014, with the error component of the standard deviation (ε) in the last column. Usage of ANOVA test to validate the fifteen variables (Table 21). The test explains variable validity; the p-value is less than 0.05 (0.00), indicating that the results are highly significant.

Table 23 Model Summary of Harvest Quantity

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.651	.423	.409	7.93310

Table 24 ANOVA Test on the Model of Harvest Quantity

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14932.153	8	1866.519	29.658	.000
	Residual	20327.700	323	62.934		
	Total	35259.853	331			

Table 25 Summary of the Regression on the Model of Harvest Quantity

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	6.797	2.735		2.486	.013		
Pre-harvest loss	5.390	2.652	.096	2.033	.043	.807	1.238
The weighted average age of trees	.225	.087	.120	2.590	.010	.829	1.207
Experience in orchard operations	-.128	.064	-.095	-1.989	.047	.788	1.269
Orchard type-Marginal	-9.235	1.857	-.390	-4.972	.000	.291	3.440
Orchard type-Small	-8.988	1.740	-.420	-5.166	.000	.270	3.699
Orchard type-Semi-Medium	-6.295	1.715	-.278	-3.672	.000	.312	3.207

Cost of fertilizer	.000	.000	.343	7.089	.000	.761	1.315
Number of picking cycles	4.112	.971	.198	4.236	.000	.819	1.221

The findings of this test, presented in Table 22, indicate that five factors significantly contributed to the harvest quantity. The contribution of each of these factors was determined using standardized β coefficients. Variance Inflation Factor (VIF) evaluates multicollinearity among the factors. All the VIF values are below 5, representing no severe multicollinearity.

7.4.2 Design of Experiments

When designing harvest quantity experiments, significant input variables and factor levels are set to their minimum and maximum historical values (D.C. Montgomery, 2013b). The regression findings are the basis of the DOE model, as shown in Figure 50. Table 23 summarizes the levels of all the considerations for the study. The 3-level design with four factors requires 3^4 randomizations, resulting in 81 experiments.

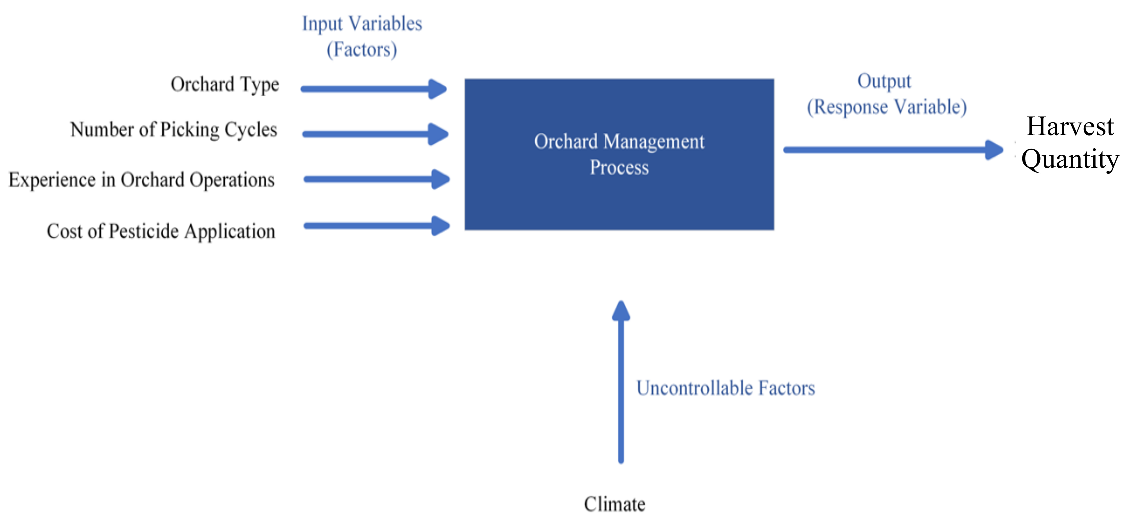


Figure 54 Orchard Management Process Model -Harvest Quantity

Table 26 Input Variables for the Model – Harvest Quantity (Response Variable)

Input Variables(Factors)	Number of Levels	Level 1	Level 2	Level 3
Orchard type	3	Marginal	Small	Semi-Medium
Number of Picking Cycles	3	1	2	3
Experience in orchard operations	3	less than 15 years	16 to 30 years	Above 30 years
Cost of Fertilizer Application	3	Less than 50000 INR	50000 to 100000 INR	Above 100000 INR

DOE is utilised to comprehend the effect of the main factor and the interaction effect on the response variable (D.C. Montgomery, 2013b). Figure 55 is a summary of the DOE model's effects.

The main factor effects that are significant impact on harvest quantity are :number of picking cycles, experience in orchard operations, cost of fertilizer, orchard type.

Interaction factor effects that are significant impact on harvest quantity are: orchard type and number of picking cycles, orchard type and cost of fertilizer, cost of fertilizer and number of picking cycles, experience in orchard operations and number of picking cycles, experience in orchard operations and cost of fertilizer, experience in orchard operations and orchard type.

Source	Logworth	PValue
Orchard Type*Number of Picking Cycles	24.584	0.00000
Orchard Type*Cost of Fertilizer	24.022	0.00000
Cost of Fertilizer*Number of Picking Cycles	17.444	0.00000
Experience in Orchard Operations*Number of Picking Cycles	17.153	0.00000
Experience in Orchard Operations*Cost of Fertilizer	15.862	0.00000
Experience in Orchard Operations	13.932	0.00000 ^

Source	Logworth	PValue
Orchard Type	12.880	0.00000 ^
Number of Picking Cycles	12.668	0.00000 ^
Cost of Fertilizer	11.651	0.00000 ^
Experience in Orchard Operations*Orchard Type	10.039	0.00000

Figure 55 Effects Summary- Design of Experiments for Harvest Quantity

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	39	2394.6285	61.4007	56.2521
Error	160	174.6444	1.0915	**Prob > F**
C. Total	199	2569.2729		<.0001*

Figure 56 Analysis of Variance for Harvest Quantity

The analysis of variance for the DOE runs for mango harvest quantity are shown in Figure 55. The model can account for a substantial proportion of the observed variation (higher value of the model sum of squares). And p-value of less than 0.05. The prior observations demonstrate that the findings about their impact on harvest quantity and the conclusion reached from those data are statistically significant. From parameter estimates, we inferred that several factors and their interactions affect harvest quantity (Figure 56).

Term	Estimate	Std Error	t Ratio	Prob>|t|
Experience in Orchard Operations[Below 15]	1.1403002	0.145604	7.83	<.0001*
Experience in Orchard Operations[15 to 30]	-1.118426	0.149945	-7.46	<.0001*
Orchard Type[Marginal]	0.7830152	0.182627	4.29	<.0001*
Orchard Type[Small]	-0.979018	0.182627	-5.36	<.0001*
Orchard Type[Semi-Medium]	1.0538972	0.182627	5.77	<.0001*
Cost of Fertilizer[Below 50000]	0.9862898	0.148183	6.66	<.0001*
Cost of Fertilizer[50000 to 100000]	-1.063385	0.149245	-7.13	<.0001*
Number of Picking Cycles[1]	1.0201081	0.148183	6.88	<.0001*
Number of Picking Cycles[2]	-1.130285	0.149245	-7.57	<.0001*
Experience in Orchard Operations[Below 15]*Orchard Type[Marginal]	1.0213869	0.252729	4.04	<.0001*
Experience in Orchard Operations[Below 15]*Orchard Type[Small]	-0.943248	0.252729	-3.73	0.0003*
Experience in Orchard Operations[Below 15]*Orchard Type[Semi-Medium]	1.1285888	0.252729	4.47	<.0001*
Experience in Orchard Operations[15 to 30]*Orchard Type[Marginal]	-0.811601	0.261006	-3.11	0.0022*
Experience in Orchard Operations[15 to 30]*Orchard Type[Small]	1.1361856	0.261006	4.35	<.0001*
Experience in Orchard Operations[15 to 30]*Orchard Type[Semi-Medium]	-1.209803	0.261006	-4.64	<.0001*
Experience in Orchard Operations[Below 15]*Cost of Fertilizer[Below 50000]	0.8405718	0.205681	4.09	<.0001*

Term	Estimate	Std Error	t Ratio	Prob>|t|
Experience in Orchard Operations[Below 15]*Cost of Fertilizer[50000 to 100000]	-0.9296	0.206447	-4.50	<.0001*
Experience in Orchard Operations[15 to 30]*Cost of Fertilizer[Below 50000]	1.1008828	0.211862	5.20	<.0001*
Experience in Orchard Operations[15 to 30]*Cost of Fertilizer[50000 to 100000]	-0.84687	0.214167	-3.95	0.0001*
Experience in Orchard Operations[Below 15]*Number of Picking Cycles[1]	0.8426255	0.205681	4.10	<.0001*
Experience in Orchard Operations[Below 15]*Number of Picking Cycles[2]	-0.854232	0.206447	-4.14	<.0001*
Experience in Orchard Operations[15 to 30]*Number of Picking Cycles[1]	1.0936538	0.211862	5.16	<.0001*
Experience in Orchard Operations[15 to 30]*Number of Picking Cycles[2]	-1.134113	0.214167	-5.30	<.0001*
Orchard Type[Marginal]*Cost of Fertilizer[Below 50000]	1.2091709	0.259421	4.66	<.0001*
Orchard Type[Marginal]*Cost of Fertilizer[50000 to 100000]	-1.137684	0.260179	-4.37	<.0001*
Orchard Type[Small]*Cost of Fertilizer[Below 50000]	0.9238947	0.253896	3.64	0.0004*
Orchard Type[Small]*Cost of Fertilizer[50000 to 100000]	-0.879528	0.260207	-3.38	0.0009*
Orchard Type[Semi-Medium]*Cost of Fertilizer[Below 50000]	0.9883247	0.253896	3.89	0.0001*
Orchard Type[Semi-Medium]*Cost of Fertilizer[50000 to 100000]	-0.923722	0.260207	-3.55	0.0005*
Orchard Type[Marginal]*Number of Picking Cycles[1]	1.1996254	0.253896	4.72	<.0001*
Orchard Type[Marginal]*Number of Picking Cycles[2]	-1.000776	0.260207	-3.85	0.0002*
Orchard Type[Small]*Number of Picking Cycles[1]	0.7636405	0.259421	2.94	0.0037*
Orchard Type[Small]*Number of Picking Cycles[2]	-0.742994	0.254314	-2.92	0.0040*
Orchard Type[Semi-Medium]*Number of Picking Cycles[1]	1.0273374	0.259421	3.96	0.0001*
Orchard Type[Semi-Medium]*Number of Picking Cycles[2]	-1.379744	0.260179	-5.30	<.0001*
Cost of Fertilizer[Below 50000]*Number of Picking Cycles[1]	1.1339142	0.207289	5.47	<.0001*
Cost of Fertilizer[Below 50000]*Number of Picking Cycles[2]	-1.041636	0.21082	-4.94	<.0001*
Cost of Fertilizer[50000 to 100000]*Number of Picking Cycles[1]	0.7611991	0.21082	3.61	0.0004*
Cost of Fertilizer[50000 to 100000]*Number of Picking Cycles[2]	-0.97158	0.211647	-4.59	<.0001*

Figure 57 Parameter Estimates for Harvest Quantity

Figure 58 depicts the Prediction Profiler, which enables interactive examination of the effect on the response variable when individual factor level parameters are modified while the other factors remain constant (D.C. Montgomery, 2013b). In Figure 58, the response variable (harvest quantity) is plotted on the Y-axis, while the factors are plotted on the X-axis. The optimal levels for marginal orchard farmers are one picking cycle, with up to 15 years of experience and investing at least 50000 INR for fertilizers (Figure 58). The optimal levels for small orchard farmers is two picking cycles, with 15 to 30 years of experience, and investing upto 50000 to 100000 INR for fertilizers.

The desirability function is rated on a scale from 0 to 1, with 1 denoting the most desirable outcome. The desirability function is used to evaluate the model's suitability in terms of data conformance and outcome prediction. This scenario's pre-harvest loss model has a desirability score of 0.999, indicating that it is highly desirable in both marginal and small orchards (D.C. Montgomery, 2013b).

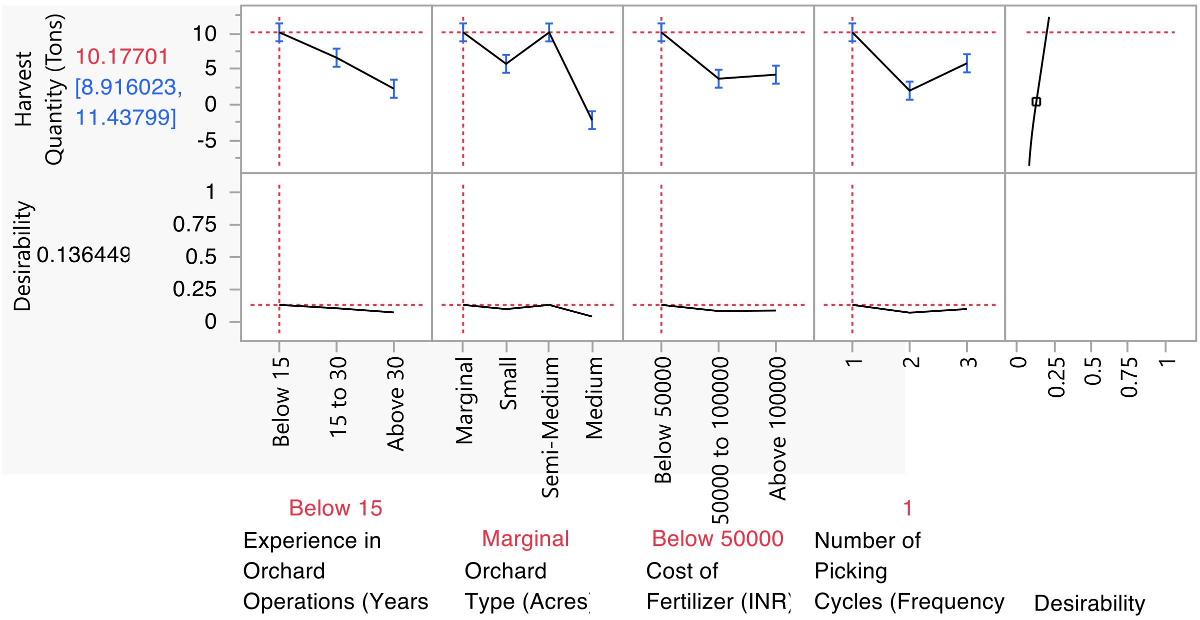


Figure 58 Prediction Profiler – Marginal Orchard for Harvest Quantity

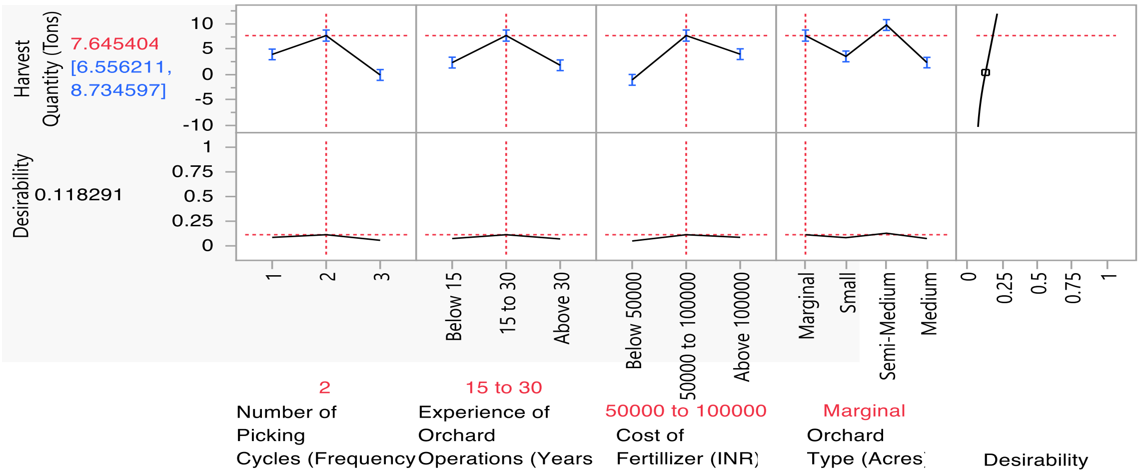


Figure 59 Prediction Profiler – Small Orchard for Harvest Quantity

7.5 Managerial Implications

By conducting the study on factors impacting the harvest quantity of mango, we have inferred the following implications and provided guidance to marginal and small farmers (Table 27).

Table 27 Guidance to Marginal and Small Orchard Farmers

Factors	Guidance to Marginal and Small Orchard Farmers
Experience in Orchard Operations	Preferred up to 30 years
Number of Picking Cycles	One Picking cycle – Marginal Orchard Two picking cycles – Small Orchard
Cost of Fertilizer	Investing at least 50000 INR – Marginal Orchard Investing 50000 to 100000 INR – Small Orchard

The number of picking cycles in a harvest season impacts the harvest quantity of mangoes. Usually, a farmer picks their mangoes once the fruit reaches its maturity, as it is not possible for some mangoes to mature simultaneously in a year. Farmers tend to pick according to the market rates before maturity or the over-ripe stage to reduce the cost of picking and transporting multiple times. It is identified from our study that increasing the number of picking cycles should be two to improve harvest quantity and also help in reducing harvest losses. To validate our findings, experts confirmed that harvesting mangoes at optimal maturity improves harvest quantity.

Experience in orchard operations plays a significant role in increasing the harvest quantity. From the results, we inferred that farmers/hired managers/pre-harvest contractors with experience between up to 30 years help in achieving more production from mango trees. To validate our findings, we contacted experts who assert that even with experience of above 30 years, it is difficult to improve the harvest quantity due to a lack of awareness of new techniques or their commitment to conventional practice.

The cost of fertilizer application significantly impacts the harvest quantity; to validate our findings, we contacted experts, who confirmed that fertilizer plays a vital role in improving harvest quantity.

Orchard type also significantly impacts harvest quantity; the larger size of the orchard, the count of trees increases, resulting in more harvest quantity. However, most of the population in the study area represents marginal and small orchard types; they need to adapt to our results to increase the harvest quantity.

It identified that interaction among the factors impacts maximizing harvest quantity. Experience in orchard operations and cost of fertilizer application; experience in orchard operations and orchard type; the number of picking cycles and cost of fertilizer application; the number of picking cycles and orchard type; orchard type and cost of fertilizer application have an interaction effect on harvest quantity.

7.6 Conclusion

From the mango orchard to the mandi, this research seeks to identify the factors affecting the mangoes' harvest quantity. Telangana's three districts Jangaon, Ranga Reddy, and Yadadri Bhuvanagiri were considered for this study. We conducted face-to-face interviews to obtain information for designing a structured questionnaire. Respondents who participated in the survey included farmers, hired managers, and pre-harvest contractors. The total number of responses collected from the three districts was 332. The fourth objective of the research is to investigate the factors impacting the harvest quantity of mangoes in the supply chain and to suggest recommendations to farmers to increase the harvest quantity. This chapter achieves this objective by identifying important issues and providing assistance to orchard managers and small producers alike.

After cleaning the collected data, we chose multiple regression as the appropriate analytical approach. The study utilizes version 26 of the SPSS statistical tool. The purpose of the initial regression was to understand better the factors that affected the harvest quantity of 332 respondents. The regression results revealed that harvest quantity is affected by pre-harvest loss, experience in orchard operations, orchard type, the weighted average age of trees, fertilizer application cost, and picking cycles. We have conducted a DOE on the significant factors received from regression results to understand the factor effect and interaction effect on harvest quantity. The results revealed that the number of picking cycles, experience in orchard operations, cost of fertilizer application, and orchard type significantly impacted harvest quantity. Also, the interaction among the factors had an impact on harvest quantity, such as experience in orchard operations and cost of fertilizer application; experience in orchard operations and orchard type; the number of picking cycles and cost of fertilizer application; the number of picking cycles and orchard type; orchard type and cost of fertilizer application.

8 CHAPTER: CONCLUSION AND FUTURE RESEARCH DIRECTIONS

Mango is one of India's most widely grown fruits. Mango orchard operations significantly impact fruit quantity, harvest quality, and supply chain losses. This study investigated Telangana's three districts Jangaon, Rangareddy, and Yadadri Bhuvanagiri. We performed in-person interviews to gather data to develop a structured questionnaire. Farmers hired managers, and pre-harvest contractors were among the survey participants. Three hundred thirty-two responses were total from the three districts.

For each of the four objectives, a different sample size is used. The 4th chapter focused on pre-harvest losses in mango supply chain, the sample selected for this study was 302, medium farmers were dropped in this research as the they represent only 2 percent of the population.

Chapter 5 focused on harvest losses, sample selected for this research were only marginal and small farmers i.e., 205 respondents. Because the focus was on marginal and small farmers (92% of the population), and the research objectives explicitly say that the guidance is to be offered for these farmers.

For the third objective on harvest quality the sample size selected was 240, including all the respondents who have not sorted. As the proxy for quality was size of mango, all the respondents who have not sorted their mangoes were dropped from the study. Medium orchard farmers are chosen for the harvest quantity study with the fact that the quantity produced by marginal farmers is almost identical to that of medium farmers. Therefore, a total of 332 responses were selected in the chapter on harvest quantity, taking into account the medium farmers was crucial.

After cleaning the gathered data, we determined that multiple regression was the most suitable analytic method. The research employs version 26 of the SPSS statistical software. The objective of the initial regression was to gain a deeper understanding of the factors influencing the response variables. The design of experiments was used on the significant factors from regression results.

Pre-harvest losses in the mango supply chain are measured by the proportion of fruit lost between the post-flowering fruit set and pre-mature stages. A conceptual framework was developed to determine the elements that affect mango supply chain losses. We selected 15 possible parameters from the literature review and expert interviews. Experience in orchard operations, orchard type - marginal and small, orchard management, district -Jangaon, and pesticide application frequency impacted pre-harvest losses, according to the initial regression model. Based on these significant components, we designed studies to investigate the factor effect and interaction effect on pre-harvest losses. Interactions between factors affected pre-harvest losses, including orchard management and orchard type, pesticide application frequency and orchard management, orchard management, orchard operations experience, pesticide application frequency and orchard type, and orchard type and orchard operations experience.

The percentage of overripe fruits lost owing to a lack of planning was used to determine harvest losses in the mango supply chain. A conceptual framework based on ten potential elements was identified through a literature review and in-depth interviews with horticultural experts. We have identified the elements that influence harvest losses, including mango orchard management expertise, pesticide application frequency, and the number of picking cycles. There is also an interaction effect of factors on harvest losses between the number of picking cycles and orchard operating experience, the number of picking cycles and pesticide application frequency, pesticide application frequency, and orchard operations.

The literature emphasizes the need for an in-depth harvest quality analysis during the harvesting stages. This study examines the elements influencing mango harvest quality, particularly in mango orchards. Based on the results of our literature review and in-depth interviews with horticultural experts, we developed a conceptual model with 19 elements. We have selected the parameters that affect the harvest quality, which include the number of picking cycles, the cost of fertilizer, the diversity of fertilizers used, the variety of pesticides used, and the frequency of pesticide application.

The regression results demonstrated that pre-harvest loss, orchard management expertise, orchard type, the weighted average age of trees, fertilizer application cost, and picking cycles influence production amount. To investigate the factor effect and interaction effect on harvest quantity, we did a DOE on the significant factors identified by regression. The findings showed that harvest quantity was highly influenced by the number of picking cycles, experience in orchard operations, cost of fertilizer application, and orchard type. In addition, the interaction between the factors affected harvest quantity, such as experience in orchard operations and cost of fertilizer application; experience in orchard operations and orchard type; the number of picking cycles and cost of fertilizer application; the number of picking cycles and orchard type; orchard type and cost of fertilizer application.

Limitations of the research

The calculated sample size is 385, however only 332 responses were collected as the process of obtaining the trust and cooperation of farmers for the purpose of data collection had been time-intensive work. Because of time constraints, data collection for the full calculated sample size was not possible.

The pricing information at the mandi could not be acquired. It was the subsequent phase of the research that aimed at understanding the buyer-seller relationship.

Farmers were unable to respond to queries related to quantities of fertilizer and pesticide used for their practices. We had to drop these variables that could have potentially served as significant additions to this research.

Future Research Scope

The results obtained for picking cycles of harvest quality study are different from that of other studies. Guidance for improving harvest quality suggest one picking cycle, however, to improve harvest quantity and reduce harvest losses, two picking cycles are recommended through analysis in this research. Future research can focus on validating the findings with mango producers and concluding the analysis would indeed be a beneficial next step. By collecting feedback and insights from the farmers themselves, it is possible to confirm the accuracy and applicability of the findings and obtain a deeper understanding of their experiences and perspectives.

In addition, if pricing information would have been available the buyer-seller relationship in the mango supply chain would be an important area for future study. Understanding the dynamics, interactions between buyers and suppliers can shed light on negotiation procedures, pricing mechanisms, and overall supply chain efficiency. This research can help in building the theory and identify areas for refinement, propose strategies for enhancing cooperation and fairness, and ultimately contribute to a more efficient mango supply chain.

Conducting these additional research activities can strengthen the overall validity and applicability of findings, contribute to the body of knowledge in mango supply chains, and potentially contribute to the development of interventions or policies aimed at enhancing the mango industry.

Investigating the effects of supply chain visibility in the mango supply chain is vital, mainly through technology and data analytics. This involves understanding the benefits of real-time information exchange and tracking technology for increasing supply chain efficiency, reducing waste, and improving product harvest quality. Investigate the potential impact of sustainable practices in the mango supply chain, such as using renewable energy, reducing carbon footprint, and water conservation. The goal could be to reduce environmental impact while maintaining product harvest quality and supply chain effectiveness.

Focus on improving food safety and harvest quality in the mango supply chain, particularly regarding food-borne illnesses and harvest quality loss during transport and storage. This may involve identifying crucial control points for harvest quality assurance, devising new packaging and storage options, and analyzing the impact of supply chain disruptions on product harvest quality. Examine measures to improve market access for marginal and small farmers and merchants in the mango supply chain, particularly in emerging markets. This includes analyzing ways to eliminate entry barriers, such as regulatory constraints and certification requirements, and implementing tactics to improve competitiveness and profitability.

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LIST OF PUBLICATIONS

1. Krishna Manasvi J., Matai Rajesh, Murthy Nagesh, Identifying factors determining the quality of mango: A design of experiments assessment. Accepted– Journal of Agribusiness in Developing and Emerging Economies. DOI: 10.1108/JADEE-04-2023-0086.
2. Krishna Manasvi J., Matai Rajesh and Murthy, Nagesh (2023). "Analytical Evaluation of Mango Harvest Losses - A Design of Experiments Approach," *IEEE 8th International Conference on Convergence of Technology (I2CT) 2023*
3. Krishna Manasvi, J., Matai, R. (2022). Agri-fresh Supply Chain Management: A Systematic Literature Review. In: Agrawal, R., Jain, J.K., Yadav, V.S., Manupati, V.K., Varela, L. (eds) Recent Advances in Industrial Production. ICEM 2020. Lecture Notes in Mechanical Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-16-5281-3_43

In Process

1. Krishna Manasvi J., Matai Rajesh, Murthy Nagesh, Identifying Factors Determining the Production Quantity of Mango: A Design of Experiments Approach. **Submitted to**– International Journal of Productivity and Performance Management (ABDC)
2. Krishna Manasvi J., Matai Rajesh, Murthy Nagesh, Reducing Mango Supply Chain Losses in India: A Sustainable Orchard Operations Perspective. **Submitted to**– Benchmarking: An International Journal (ABDC)

APPENDIX - A

QUESTIONNAIRE FOR MANGO SUPPLY CHAIN - ORCHARD OPERATIONS

Please provide the following general information

1. Name	
2. Gender	
3. Age	
4. Occupation	
5. Phone Number	
6. Highest Educational Qualification	
7. Years of experience in mango farming	
8. Number of Family members performing farming activities in your orchard	
9. Annual Income (from mango orchard)	
10. Village (where the orchard is located)	
11. District (where the orchard is located)	

12. Who manages the day-to-day activities at your orchard? Please check all appropriate boxes.

☐ Self
☐ Hired manager
☐ Other _______________

13. What is the area of the land used for mango cultivation in your orchard?

☐ Up to 2.5 acres
☐ 2.5 to 5 acres
☐ 5 to 7.5acres
☐ 7.5 to 10 acres
☐ More than 10 acres
☐ Other - Please specify the precise area (in acres) if known _________________

14. What are the varieties of mango produced in your orchard?

☐ Banganapalli ☐ Dasheri
☐ Totapuri ☐ Neelum
☐ Suvarnarekha ☐ Pandla Rasalu
☐ Mallika ☐ Others - Please specify _______________

15. Please specify the approximate range for the number of trees of each variety in your orchard that falls in the following age groups?

	Below 10 Years	**10 to 20 Years**	**20 to 30 Years**	**30 to 40 Years**	**40 to 50 Years**	**50 Years and above**

Banganapalli						
Totapuri						
Neelum						
Suvarnarekha						
Dasheri						
Pandla Rasalu						
Mallika						
Others-Please specify ________						

16. Please indicate your primary source of information regarding the quantities and prices of mangoes being sold at the collection center in last three weeks prior to the planned week for picking and transporting mangoes to the collection center
    - ☐ Website
    - ☐ Pre-harvest Contractor
    - ☐ Post-harvest buyer
    - ☐ Commission agent
    - ☐ Other Farmers
    - ☐ Other- please specify_________

17. Please indicate whether you are aware of the following websites. Please check the appropriate boxes.

WEBSITE	YES	NO
Agriculture Market Government of India		
Agricultural Marketing Department Government of Telangana		
National Horticulture Board, Government of India		
Department of Agriculture and Farmers Welfare, Government of India		
IMD (Indian Metrological Department)		

18. Please indicate the extent to which you check the market prices from Agriculture Market Government of India website.

1	2	3	4	5	6	7
Rarely	Once in the mango season	Once in a month	Once every week	Thrice every week	Five times a week	Daily

19. Please indicate the extent to which you check the market prices from the Agricultural Marketing Department Government of Telangana website.

1	2	3	4	5	6	7
Rarely	Once in the mango season	Once in a month	Once every week	Thrice every week	Five times a week	Daily

20. Please indicate the extent to which you check the schemes from Department of Agriculture and Farmers Welfare, Government of India website.

1	2	3	4	5	6	7
Rarely	Once in the mango season	Once in a month	Once every week	Thrice every week	Five times a week	Daily

21. Please indicate the extent to which you check the climatic conditions from IMD (Indian Metrological Department) for each picking cycle

1	2	3	4	5	6	7
Rarely	Once in the mango season	Once in a month	Once every week	Thrice every week	Five times a week	Daily

22. Please indicate how often you check the prices of mangoes for each variety on your orchard during the harvest season. Please check the appropriate boxes.

1	2	3	4	5	6	7
Rarely	Once in the mango season	Once in a month	Once every week	Thrice every week	Five times a week	Daily

23. Please indicate the extent to which you are aware of the following with regards to collection centers in your state

1	2	3	4	5	6	7
I know of only the collection center closest to me	I know of only the two closest collection centers to me	I know of the four closest collection centers to me	I know of the six collection centers in Telangana	I know of the eight collection centers in Telangana	I know of the ten collection centers in Telangana	I know of all collection centers

24. Please indicate the extent to which you are aware of the availability of pre-harvest contractors in your district

1	2	3	4	5	6	7
I do not know any of them	I know very few of them	I know a few of them	I know some of them	I know many of them	I know most of them	I know all of them

25. Please indicate the extent to which you can estimate the rate at which orchard is leased to pre-harvest contractors

1	2	3	4	5	6	7
I have no idea	I have very little idea	I have a little idea	I have some idea	I have a fair idea	I have a good idea	I have a very good idea

26. Please indicate the extent to which you are aware of the availability of post-harvest buyers in your district

1	2	3	4	5	6	7
I do not know any of them	I know very few of them	I know a few of them	I know some of them	I know many of them	I know most of them	I know all of them

27. Please indicate the extent to which you can estimate the cost incurred by the post-harvest buyer for harvesting the produce and transporting it to the collection center

1	2	3	4	5	6	7
I have no idea	I have very little idea	I have a little idea	I have some idea	I have a fair idea	I have a good idea	I have a very good idea (as I have done it myself in the past)

28. Please tick the following insurance schemes that you are aware of
    ☐ Pradhan Mantri Fasal Bima Yojana
    ☐ Weather Based Crop Insurance Scheme
    ☐ Unified Package Insurance Scheme
    ☐ Others-Please specify ___________________________

29. Did you take any insurance for your mango orchard?
    ☐ Yes ☐ No

30. If no, please specify the reasons for not taking insurance for your mango orchard.
    ____

31. Are you aware of Kisan credit cards?
    ☐ Yes ☐ No

32. Do you have a Kisan credit card?
    ☐ Yes ☐ No

33. Please indicate the extent to which you use a Kisan credit card.

1	2	3	4	5	6	7
Rarely	Once in six months	Once every three months	Twice every three months	Once in a month	Twice a month	Once a week

34. Are you aware that you could get loans for the below options?
    ☐ Running the day-to-day operations
    ☐ Buying farm machinery such as tractors, drip irrigation
    ☐ Purchasing land
    ☐ Storage purposes
    ☐ Product marketing loans
    ☐ Other- Please specify ___________
35. Did you take any loans for your mango orchard?
    ☐ Yes ☐ No
36. If yes, please check all the reasons below for which the loan was taken.
    ☐ Running the day-to-day operations
    ☐ Buying farm machinery such as tractors, drip irrigation
    ☐ Purchasing land
    ☐ Storage purposes
    ☐ Product marketing loans
    ☐ Other- Please specify ___________
37. Have you defaulted on any of your loans related to managing your mango orchard in the last five years?
    ☐ Yes ☐ No
38. Do you hire pre-harvest contractors to harvest mangoes in your orchard and lease the orchard to pre-harvest contractors during the harvest season?
    ☐ Yes
    ☐ No
    If "Yes," then collect contact details for the pre-harvest contractor.
    Name: _______________
    Phone Number: _______________
39. When was the leasing contract signed with the pre-harvest contractor for the harvesting season.? (If applicable)

	January	February	March	April	May	June	July	August	September	October	November	December
Other (______)												
2020												
2021												

40. If the land is leased to pre-harvest contractor, what is the price received by the farmer? (If applicable) _______________

41. In which month was the payment received by the Farmer from the pre-harvest contractor? Please provide the percentage of payment if multiple payments are made. (If applicable)

	January	February	March	April	May	June	July	August	September	October	November	December
2020												
2021												

42. Did you sell your mangoes from your orchard to a post-harvest buyer during the harvest season?
☐ Yes
☐ No
If "Yes," then collect contact details for the post-harvest buyer
Name: _______________
Phone Number: _______________

43. Please indicate all the activities undertaken at your orchard during the year by the Farmer or the pre-harvest contractor or post-harvest buyer. (Please check all appropriate boxes)

	Activities performed by a farmer	Activities performed by a pre-harvest contractor	Activities performed by a Post-harvest buyer
Pruning/Trimming			
Application of pesticides (Dec to March)			
Application of fertilizers (April to July)			
Irrigation (Post-harvest and prior to flowering)			
Irrigation (Flowering)			
Irrigation (Harvesting)			
Picking mangoes manually			
Picking mangoes using net			
Desapping			
Sorting			
Washing			
Packing into crates			
Storage in farm prior to taking it into a collection center			
Loading into vehicles for transportation to the collection center			

44. Please indicate the approximate percentage of mangoes from your farm sold in each of the following marketing/ distribution channels.

Market	Percentage
Pre-harvest Contractor (Wherein the contractor performs the harvesting)	
Post-harvest buyer (Wherein the Farmer performs the harvesting)	
APMC (Collection Center)- (Wherein the Farmer performs the harvesting and transports the produce to the collection center for auction using a commission agent)	
Village market	
City Market	
Other-Please specify ____________________________	
Total	

45. Which of the following fertilizers were used at your orchard in 2021? Please check all the suitable options.

☐ Nitrogen- Phosphorous- Potassium based fertilizer (i.e., NPK)
☐ Zinc based fertilizer
☐ Natural liquid fertilizer (Jeevamruth)
☐ Vermi Compost
☐ Urea
☐ Super (Phosphorus, Sulphur and Calcium based fertilizer)
☐ Others - Please specify ________________

46. Please specify the months in which each fertilizer type was used at the orchard during the following months in 2020 and 2021?

	Nitrogen-Phosphorous-Potassium based fertilizer (i.e., NPK)		Zinc Based Fertilizer		Natural liquid fertilizer		Vermi Compost		Urea		Super (Phosphorus, Sulphur and Calcium based fertilizer)		Others__ ________ ________ ________ ________ _	
	2020	2021	2020	2021	2020	2020	2020	2021	2021	2021	2020	2021	2020	2021
January														
February														
March														
April														

May														
June														
July														
August														
September														
October														
November														
December														

47. What was the annual cost of each fertilizer type used at your orchard in 2021?

Fertilizer used	**The annual cost of fertilizer (In Rupees)**
Nitrogen- Phosphorous- Potassium based fertilizer (i.e., NPK)	
Zinc based fertilizer	
Natural liquid fertilizer (Jeevamruth)	
Vermi Compost	
Urea	
Super (Phosphorus, Sulphur and Calcium based fertilizer)	
Others- Please specify__________________	

48. Please specify the diseases that most affect the mango trees in your orchard? Please check all appropriate boxes.

	Anthracnose		Gummosis
	Stem end rot		Scale
	Black rot		Black-banded
	Powdery Mildew		Ganoderma root rot
	Die Back		Root rot and damping-off
	Sooty mold		Red rust
	Phoma blight		Lichens
	Bacterial canker		Malformation
	Mosquito		
	Others – Please specify ______________		

49. Which of the following pesticides were used at your orchard in 2021? Please check all the suitable options.
☐ Neem Oil Spray
☐ Neem seed powder
☐ Fungicide
☐ Urea
☐ Others - Please specify ________________

50. Please specify the months in which each pesticide type was used at the orchard during the following months in 2020 and 2021?

	Neem oil spray		Neem seed powder		Fungicide		Urea		Other __________	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
January										
February										
March										
April										
May										
June										
July										
August										
September										
October										
November										
December										

51. What was the annual cost of each pesticide type used at your orchard in 2021?

Pesticide used	**Cost of Pesticide (In Rupees)**
Neem oil spray	
Neem seed spray	
Fungicide	
Urea	
Other- Please specify ______________	

52. What is your annual cost for the following in the year 2021?

	(in Rupees)
Labour	
Irrigation	
Power (Electricity)	

53. Which of the following irrigation techniques are used in your orchard? Please check all applicable boxes.
☐ Basin Method
☐ Furrow Method
☐ Drip System

☐ Sprinkler System
☐ Others - Please specify ________________

54. Please indicate the approximate range of the number of days in each of the following months in 2020 and 2021, during which your orchard was irrigated using piped water supply.

	January	February	March	April	May	June	July	August	September	October	November	December
2020												
2021												

55. What is the approximate percentage of mangoes (based on the annual count of mangoes sold) lost at your orchard due to preharvest fall (i.e., all the output lost between post-flowering and pre-harvesting) in 2020? Please check the most appropriate box.
☐ 0 to less than 5% ☐ 5 to less than 10% ☐ 10 to less than 15 %
☐ 15 to less than 20% ☐ 20 to less than 25% ☐ 25 to less than 30%
☐ 30 to less than 35 %. ☐ 35 to less than 40% ☐ 40 to less than 45%
☐ 45 to less than 50% ☐ 50 to less than 55 %. ☐ 55 to less than 60%

56. What is the approximate percentage of mangoes (based on the annual count of mangoes sold) lost at your orchard due to preharvest fall (i.e., all the output lost between post-flowering and pre-harvesting) in 2021? Please check the most appropriate box.
☐ 0 to less than 5% ☐ 5 to less than 10% ☐ 10 to less than 15 %
☐ 15 to less than 20% ☐ 20 to less than 25% ☐ 25 to less than 30%
☐ 30 to less than 35 %. ☐ 35 to less than 40% ☐ 40 to less than 45%
☐ 45 to less than 50% ☐ 50 to less than 55 %. ☐ 55 to less than 60%

57. Please specify the approximate % of pre-sale harvest loss **due to overripe fruit or damaged loose fruit** as a percentage of the total quantity harvested for the season.

☐ 0 to less than 2% ☐ 2 to less than 4% ☐ 4 to less than 6%
☐ 6 to less than 8% ☐ 8 to less than 10% ☐ 10 to less than 12%
☐ 12 to less than 14% ☐ 14 to less than 16% ☐ 16 to less than 18%
☐ 18 to less than 20% ☐ 20 to less than 22% ☐ 22 to less than 24%

58. How many times did you pick mangoes in a harvesting season of 2020 and 2021? Please check the appropriate boxes.

	1	2	3	4	5
2020					
2021					

59. Which of the following issues factor into your decision on whether to pick mangoes on a given day? Please check all applicable boxes.
☐ The sizable quantity of fruit is at the desired maturity level by the desired date for harvest
☐ The sizable quantity of fruit is large-sized by the desired date of harvest
☐ A significant quantity of overripe or damaged loose fruit appears on the ground by the desired date of harvest
☐ Labour availability
☐ Transportation availability
☐ Storage availability
☐ Market rate

☐ Avoid loss due to imminent inclement weather conditions (i.e., to harvest prior to any forecast for heavy rainfall or high windspeeds)
☐ Other - Please specify ____________________

60. Please specify the following based on each picking cycle on your orchard.

	Picking 1	Picking 2	Picking 3	Picking 4	Picking 5
Week of the month when harvesting took place					
Did you experience any delay in harvesting (Yes/No)					
If yes, how many days of delay?					
The primary reason for the delay (please check all applicable boxes only when you could not harvest on the desired day - otherwise, leave all boxes for that picking cycle unchecked)	☐Labour availability ☐Transportation availability ☐Storage availability ☐Market rate ☐Climatic conditions ☐Other ________	☐Labour availability ☐Transportation availability ☐Storage availability ☐Market rate ☐Climatic conditions ☐Other ________	☐Labour availability ☐Transportation availability ☐Storage availability ☐Market rate ☐Climatic conditions ☐Other ________	☐Labour availability ☐Transportation availability ☐Storage availability ☐Market rate ☐Climatic conditions ☐Other ________	☐Labour availability ☐Transportation availability ☐Storage availability ☐Market rate ☐Climatic conditions ☐Other ________

61. Please specify the collection centre at which your harvest is auctioned

___

62. What is the approximate distance from your orchard to the collection centre?

☐ Less than 20 kms
☐ 20 to 40 kms
☐ 40 to 60 kms
☐ 60 to 80 kms
☐ 80 to 100 kms
☐ 100 to 120 kms
☐ 120 to 140 kms
☐ More than 140 kms

63. Please specify the quantity details of the mangoes sold in the market for each picking cycle respectively for the year 2021.

		Picking 1	Picking 2	Picking 3	Picking 4	Picking 5
Variety 1 ________	The total quantity of mangoes transported to the collection center					
	Were the mangoes sorted by size (Yes/No)					
	If yes, the quantity of small-sized mangoes					

	If yes, the quantity of medium and large-sized mangoes					

		Picking 1	Picking 2	Picking 3	Picking 4	Picking 5
Variety 2 ________	The total quantity of mangoes					
	Were the mangoes sorted by size (Yes/No)					
	If yes, the quantity of small-sized mangoes					
	If yes, the quantity of medium and large-sized mangoes					

64. Please specify the price details of the mangoes produced and sold in the market for each picking cycle respectively for the year 2021.

		Picking 1	Picking 2	Picking 3	Picking 4	Picking 5
Variety 1 ________	Total price received for mangoes					
	Price received for small-sized mangoes					
	Price received for medium and large-sized mangoes					

		Picking 1	Picking 2	Picking 3	Picking 4	Picking 5
Variety 2 ________	Total price received for mangoes					
	Price received for small-sized mangoes					
	Price received for medium and large-sized mangoes					

65. Please specify the labour and transportation details for each picking cycle, respectively

	Picking 1	Picking 2	Picking 3	Picking 4	Picking 5
Number of labourers used					
Average wage per labourer (per day)					
Transportation Cost					

APPENDIX – B

మామిడి తోట కార్యకలాపాల కొరకు ప్రశ్నావళి

దయచేసి దిగువ సాధారణ సమాచారాన్ని అందించండి

1) పేరు	
2) పురుషుడు / స్త్రీ	
3) వయస్సు	
4) వృత్తి	
5) ఫోన్ నంబర్	
6) అత్యున్నత విద్యార్హతలు	
7) మామిడి వ్యవసాయంలో సంవత్సరాల అనుభవం	
8) మీ తోటలో వ్యవసాయ కార్యక్రమాలు చేస్తున్న కుటుంబ సభ్యుల సంఖ్య	
9) వార్షిక ఆదాయం (మామిడి తోట నుండి)	
10) గ్రామం (తోట ఉన్న చోట)	
11) జిల్లా (తోట ఉన్న చోట)	

12) మీ తోటలో రోజువారీ కార్యకలాపాలను ఎవరు నిర్వహిస్తారు? దయచేసి అన్ని తగిన బాక్సులను చెక్ చేయండి.

☐ తనకు తాను

☐ అద్దె మేనేజర్

☐ ఇతర ______________

13) మీ తోటలో మామిడి సాగుకు ఉపయోగించే భూమి వైశాల్యం ఎంత?

☐ 2.5 ఎకరాల వరకు

☐ 2.5 నుంచి 5 ఎకరాలు

☐ 5 నుంచి 7.5ఎకరాలు

☐ 7.5 నుంచి 10 ఎకరాలు

☐ 10 ఎకరాలకు పైగా

☐ ఇతరాలు - ఒకవేళ తెలిసినట్లయితే ఖచ్చితమైన ప్రాంతాన్ని (ఎకరాల్లో) పేర్కొనండి.....................

14) మీ తోటలో ఉత్పత్తి అయ్యే మామిడి రకాలు ఏమిటి?

☐ బంగానపల్లి

☐ తోటాపురి

☐ నీలుం

☐ సువర్ణ రేఖ

☐ దషేరి

☐ పండ్ల రసాలు

☐ మల్లిక

☐ ఇతరులు - దయచేసి ___ పేర్కొనండి

15) దిగువ వయస్సు గ్రూపుల్లో వచ్చే మీ తోటలోని ప్రతి రకం చెట్ల సంఖ్య కొరకు సుమారుగా శ్రేణిని దయచేసి పేర్కొనండి.

	10 సంవత్సరాల కంటే తక్కువ	10 నుంచి 20 సంవత్సరాలు	20 నుంచి 30 సంవత్సరాలు	30 నుంచి 40 సంవత్సరాలు	40 నుంచి 50 సంవత్సరాలు	50 సంవత్సరాలు మరియు పైన
బంగానపల్లి						
తోటాపురి						
నీలుం						
సువర్ణ రేఖ						
దషేరి						
పండ్ల రసాలు						
మల్లిక						
ఇతరులు - దయచేసి పేర్కొనండి_____ _____________						

16) మామిడి పండ్లను సేకరణ కేంద్రానికి పికప్ చేసుకోవడానికి మరియు రవాణా చేయడానికి ప్లాన్ చేయబడ్డ వారానికి ముందు గత మూడు వారాల్లో కలెక్షన్ సెంటర్ వద్ద విక్రయించే మామిడి పండ్లు యొక్క పరిమాణాలు మరియు ధరలకు సంబంధించిన మీ ప్రాథమిక సమాచార వనరును దయచేసి సూచించండి.

☐ వెబ్ సైట్

☐ ప్రీ హార్వెస్ట్ కాంట్రాక్టర్

☐ కోత అనంతర కొనుగోలుదారుడు

☐ కమిషన్ ఏజెంట్

☐ ఇతర రైతులు

☐ ఇతర- దయచేసి పేర్కొనండి_________

17) ఈ క్రింది వెబ్ సైట్ల గురించి మీకు తెలుసా లేదా అని దయచేసి సూచించండి. దయచేసి తగిన బాక్సులను తనిఖీ చేయండి.

వెబ్ సైట్	అవును	కాదు
వ్యవసాయ మార్కెట్ భారత ప్రభుత్వం		
తెలంగాణ వ్యవసాయ మార్కెటింగ్ శాఖ ప్రభుత్వం		

నేషనల్ హార్టికల్చర్ బోర్డు, భారత ప్రభుత్వం		
వ్యవసాయ, రైతు సంక్షేమ శాఖ, భారత ప్రభుత్వం		
ఐఎండి (ఇండియన్ మెట్రోలాజికల్ డిపార్ట్ మెంట్)		

18) వ్యవసాయ మార్కెట్ ప్రభుత్వ వెబ్ సైట్ నుండి మార్కెట్ ధరలను మీరు ఎంత మేరకు తనిఖీ చేయాలో దయచేసి సూచించండి.

1	2	3	4	5	6	7
అరుదుగా	మామిడి సీజన్ లో ఒకసారి	నెలకు ఒకసారి	ప్రతి వారం ఒకసారి	ప్రతివారం మూడుసార్లు	వారానికి ఐదుసార్లు	రోజువారీ

19) తెలంగాణ వెబ్ సైట్ లోని వ్యవసాయ మార్కెటింగ్ శాఖ ప్రభుత్వం నుంచి మార్కెట్ ధరలను మీరు ఏ మేరకు తనిఖీ చేయాలో దయచేసి సూచించండి.

1	2	3	4	5	6	7
అరుదుగా	మామిడి సీజన్ లో ఒకసారి	నెలకు ఒకసారి	ప్రతి వారం ఒకసారి	ప్రతివారం మూడుసార్లు	వారానికి ఐదుసార్లు	రోజువారీ

20) భారత ప్రభుత్వ వెబ్ సైట్ అయిన వ్యవసాయం మరియు రైతు సంక్షేమ శాఖ నుండి మీరు పథకాలను ఏ మేరకు తనిఖీ చేయాలో దయచేసి సూచించండి.

1	2	3	4	5	6	7
అరుదుగా	మామిడి సీజన్ లో ఒకసారి	నెలకు ఒకసారి	ప్రతి వారం ఒకసారి	ప్రతివారం మూడుసార్లు	వారానికి ఐదుసార్లు	రోజువారీ

21) ప్రతి పికింగ్ సైకిల్ కొరకు ఐఎండి (ఇండియన్ మెట్రోలాజికల్ డిపార్ట్ మెంట్) నుంచి వాతావరణ పరిస్థితులను మీరు ఎంతమేరకు చెక్ చేయాలో దయచేసి సూచించండి.

1	2	3	4	5	6	7
అరుదుగా	మామిడి సీజన్ లో ఒకసారి	నెలకు ఒకసారి	ప్రతి వారం ఒకసారి	ప్రతివారం మూడుసార్లు	వారానికి ఐదుసార్లు	రోజువారీ

22) కోత కాలంలో మీ తోటలో ని ర్రకానికి మామిడి పండ్ల ధరలను ఎంత తరచుగా తనిఖీ చేయాలో దయచేసి సూచించండి. దయచేసి తగిన బాక్సులను తనిఖీ చేయండి.

1	2	3	4	5	6	7
అరుదుగా	మామిడి సీజన్ లో ఒకసారి	నెలకు ఒకసారి	ప్రతి వారం ఒకసారి	ప్రతివారం మూడుసార్లు	వారానికి ఐదుసార్లు	రోజువారీ

23) మీ రాష్ట్రంలో కలెక్షన్ సెంటర్లకు సంబంధించి దిగువ పేర్కొన్న విశదంగా మీకు ఎంత మేరకు తెలుసు అనే దానిని దయచేసి సూచించండి.

1	2	3	4	5	6	7
నాకు దగ్గరగా ఉన్న కలెక్షన్ సెంటర్ గురించి మాత్రమే నాకు తెలుసు	నాకు దగ్గరగా ఉన్న రెండు కలెక్షన్ సెంటర్ల గురించి మాత్రమే నాకు తెలుసు	నాకు నాలుగు దగ్గరి కలెక్షన్ సెంటర్ల గురించి నాకు తెలుసు	తెలంగాణలో ఆరు కలెక్షన్ సెంటర్ల గురించి నాకు తెలుసు	తెలంగాణలో ఎనిమిది కలెక్షన్ సెంటర్ల గురించి నాకు తెలుసు	తెలంగాణలో పది కలెక్షన్ సెంటర్ల గురించి నాకు తెలుసు	అన్ని కలెక్షన్ సెంటర్ ల గురించి నాకు తెలుసు

24) మీ జిల్లాలో ప్రీ హార్వెస్ట్ కాంట్రాక్టర్ల లభ్యత గురించి మీకు ఎంత మేరకు తెలుసో దయచేసి సూచించండి.

1	2	3	4	5	6	7
వాటిలో ఏదీ నాకు తెలియదు	వాటిలో నాకు చాలా తక్కువ తెలుసు	వాటిలో కొన్ని నాకు తెలుసు	వాటిలో కొంత వరకు నాకు తెలుసు	వాటిలో చాలా నాకు తెలుసు	వాటిలో చాలా వరకు నాకు తెలుసు	అవన్నీ నాకు తెలుసు

25) ప్రీ హార్వెస్ట్ కాంట్రాక్టర్లకు తోటను లీజుకు ఇచ్చే రేటును మీరు ఎంత మేరకు అంచనా వేయవచ్చో దయచేసి సూచించండి.

1	2	3	4	5	6	7
నాకు అవగాహన లేదు	నాకు చాలా తక్కువ ఆలోచన ఉంది	నాకు ఒక చిన్న ఆలోచన ఉంది	నాకు కొంత ఆలోచన ఉంద	నాకు ఒక న్యాయమైన ఆలోచన ఉంది	నాకు మంచి ఆలోచన ఉంది	నాకు చాలా మంచి ఆలోచన ఉంది

26) మీ జిల్లాలో కోత అనంతర కొనుగోలుదారుల లభ్యత గురించి మీకు ఎంత మేరకు తెలుసో దయచేసి సూచించండి.

1	2	3	4	5	6	7
వాటిలో ఏదీ నాకు తెలియదు	వాటిలో నాకు చాలా తక్కువ తెలుసు	వాటిలో కొన్ని నాకు తెలుసు	వాటిలో కొంత వరకు నాకు తెలుసు	వాటిలో చాలా నాకు తెలుసు	వాటిలో చాలా వరకు నాకు తెలుసు	అవన్నీ నాకు తెలుసు

27) ఉత్పత్తిని కోయడానికి మరియు సేకరణ కేంద్రానికి రవాణా చేయడానికి కోత అనంతర కొనుగోలుదారుడు ఎంత ఖర్చు ను అంచనా వేయగలరో దయచేసి సూచించండి.

1	2	3	4	5	6	7
నాకు అవగాహన లేదు	నాకు చాలా తక్కువ ఆలోచన ఉంది	నాకు ఒక చిన్న ఆలోచన ఉంది	నాకు కొంత ఆలోచన ఉంది	నాకు ఒక న్యాయమైన ఆలోచన ఉంది	నాకు మంచి ఆలోచన ఉంది	నాకు చాలా మంచి ఆలోచన ఉంది

28) రైతు గురించి మీకు తెలిసిన ఈ క్రింది బీమా పథకాలను దయచేసి టిక్ చేయండి.

☐ ప్రధానమంత్రి ఫసల్ బీమా యోజన

☐ వాతావరణ ఆధారిత పంట బీమా పథకం

☐ ఏకీకృత ప్యాకేజీ బీమా పథకం

☐ ఇతరులు-దయచేసి ___ పేర్కొనండి

29) మీ మామిడి తోటకు ఏదైనా బీమా చేశారా?

☐ అవును ☐ కాదు

30) ఒకవేళ లేనట్లయితే, మీ మామిడి తోటకు బీమా తీసుకోకపోవడానికి గల కారణాలను దయచేసి పేర్కొనండి

____

31) కిసాన్ క్రెడిట్ కార్డుల గురించి మీకు తెలుసా?

☐ అవును ☐ కాదు

32) మీ వద్ద కిసాన్ క్రెడిట్ కార్డు ఉందా?

☐ అవును ☐ కాదు

33) మీరు కిసాన్ క్రెడిట్ కార్డును ఎంత మేరకు ఉపయోగిస్తున్నారని దయచేసి సూచించండి.

1	2	3	4	5	6	7
అరుదుగా	ఆరు నెలలకు ఒకసారి	ప్రతి మూడు నెలలకు ఒకసారి	ప్రతి మూడు నెలలకు రెండుసార్లు	నెలకు ఒకసారి	నెలకు రెండుసార్లు	వారానికి ఒకసారి

34) దిగువ ఆప్షన్ ల కొరకు మీరు రుణాలు పొందవచ్చని మీకు తెలుసా?

☐ రోజువారీ కార్యకలాపాలను నిర్వహించడం

☐ ట్రాక్టర్లు, డ్రిప్ ఇరిగేషన్ వంటి వ్యవసాయ యంత్రాలను కొనుగోలు చేయడం

☐ భూమిని కొనుగోలు చేయడం

☐ నిల్వ ఉద్దేశ్యాలు

☐ ప్రొడక్ట్ మార్కెటింగ్ రుణాలు

☐ ఇతరాలు– దయచేసి ___ పేర్కొనండి.

35) మీ మామిడి తోటకు ఏదైనా రుణం తీసుకున్నారా?

☐ అవును ☐ కాదు

36) ఒకవేళ అవును అయితే, రుణం తీసుకున్న అన్ని కారణాలను దయచేసి చెక్ చేయండి.

☐ రోజువారీ కార్యకలాపాలను నిర్వహించడం

☐ ట్రాక్టర్లు, డ్రిప్ ఇరిగేషన్ వంటి వ్యవసాయ యంత్రాలను కొనుగోలు చేయడం

☐ భూమిని కొనుగోలు చేయడం

☐ నిల్వ ఉద్దేశ్యాలు

☐ ప్రొడక్ట్ మార్కెటింగ్ రుణాలు

☐ ఇతరాలు- దయచేసి ___ పేర్కొనండి

37) గత ఐదేళ్లలో మీ మామిడి తోట నిర్వహణకు సంబంధించిన మీ రుణాల్లో దేనినైనా మీరు డిఫాల్ట్ చేశారా?

☐ అవును ☐ కాదు

38) మీ తోటలో మామిడి పండ్లను కోయడానికి, కోత కు ముందు కాంట్రాక్టర్లకు తోటను లీజుకు ఇవ్వడానికి మీరు ప్రీ హార్వెస్ట్ కాంట్రాక్టర్లను నియమిస్తారా?

☐ అవును

☐ లేదు

ఒకవేళ "అవును" అయితే, ప్రీ హార్వెస్ట్ కాంట్రాక్టర్ కొరకు కాంటాక్ట్ వివరాలను సేకరించండి.

పేరు: ___

ఫోన్ నెంబరు: ___

39) కోత కాలానికి కాంట్రాక్టర్ తో లీజింగ్ ఒప్పందం ఎప్పుడు కుదిరింది.? (ఒకవేళ వర్తించినట్లయితే)

	జనవరి	ఫిబ్రవరి	మార్చి	ఏప్రిల్	మే	జూన్	జూలై	ఆగస్టు	సెప్టెంబర్	అక్టోబర్	నవంబర్	డిసెంబర్
ఇతర												
2021												

40) భూమిని ప్రీ హార్వెస్ట్ కాంట్రాక్టర్ కు లీజుకు ఇస్తే, రైతు పొందే ధర ఎంత? (ఒకవేళ వర్తించినట్లయితే)________________

41) కోతకు ముందు కాంట్రాక్టర్ నుంచి రైతు ద్వారా ఏ నెలలో చెల్లింపు వచ్చింది? ఒకవేళ బహుళ చెల్లింపులు జరిగినట్లయితే దయచేసి చెల్లింపు శాతాన్ని అందించండి. (ఒకవేళ వర్తించినట్లయితే)

	జనవరి	ఫిబ్రవరి	మార్చి	ఏప్రిల్	మే	జూన్	జూలై	ఆగస్టు	సెప్టెంబర్	అక్టోబర్	నవంబర్	డిసెంబర్
2021												

42) పంట కోత కాలంలో మీ మామిడి పండ్లను మీ తోట నుంచి కోత అనంతర కొనుగోలుదారుడికి అమ్మారా?

☐ అవును

☐ లేదు

ఒకవేళ "అవును" అయితే, కోత అనంతర కొనుగోలుదారుడి కొరకు కాంటాక్ట్ వివరాలను సేకరించండి.

పేరు: ___

ఫోన్ నెంబరు: ___

43) రైతు లేదా కాంట్రాక్టర్ ద్వారా సంవత్సరంలో మీ తోటలో చేపట్టే అన్ని కార్యకలాపాలను దయచేసి సూచించండి. (దయచేసి అన్ని తగిన బాక్సులను చెక్ చేయండి)

	ఒక రైతు ద్వారా నిర్వహించబడే కార్యకలాపాలు	కాంట్రాక్టర్ ద్వారా నిర్వహించబడే కార్యకలాపాలు	కోత అనంతర కొనుగోలుదారుడు నిర్వహించే కార్యకలాపాలు
కత్తిరించడం/ట్రిమ్మింగ్ చేయడం			
పురుగుమందుల అనువర్తనం (డిసెంబర్ నుంచి మార్చి వరకు)			
ఎరువుల ను అనువర్తించడం (ఏప్రిల్ నుండి జూలై)			
నీటిపారుదల (కోత అనంతరం మరియు పుష్పించడానికి ముందు)			
నీటిపారుదల (పుష్పించడం)			
నీటిపారుదల (కోత)			
మామిడి పండ్లను మాన్యువల్ గా తీయడం			
నెట్ ఉపయోగించి మామిడి పండ్లను తీయడం			
డీసప్పింగ్			
క్రమబద్ధీకరించడం			
కడగడం			
క్రేట్ ల్లో ప్యాకింగ్ చేయడం			
కలెక్షన్ సెంటర్ లోనికి తీసుకెళ్లడానికి ముందు ఫారంలో నిల్వ చేయడం			
కలెక్షన్ సెంటర్ కు రవాణా చేయడం కొరకు వాహనాల్లోకి లోడింగ్ చేయడం			

44) మీ ఫారం నుంచి దిగువ పేర్కొన్న ప్రతి మార్కెటింగ్/డిస్ట్రిబ్యూషన్ ఛానల్స్ లో విక్రయించబడ్డ మామిడి పండ్ల యొక్క సుమారు శాతాన్ని దయచేసి సూచించండి.

సంత	శాతం
ప్రీ హార్వెస్ట్ కాంట్రాక్టర్ (ఇందులో కాంట్రాక్టర్ కోత ను నిర్వహిస్తాడు)	
కోత అనంతర కొనుగోలుదారుడు (ఇందులో రైతు కోత చేస్తాడు)	

APMసి (కలెక్షన్ సెంటర్)- (ఇందులో రైతు కోత ను నిర్వహించాలి మరియు ఒక కమీషన్ ఏజెంట్ ఉపయోగించి ఉత్పత్తిని వేలం కొరకు కలెక్షన్ సెంటర్ కు రవాణా చేస్తాడు)	
గ్రామ మార్కెట్	
నగర మార్కెట్	
ఇతరాలు-దయచేసి ___ పేర్కొనండి.	
మొత్తం	

45) 2021లో మీ తోటలో ఈ క్రింది ఎరువులలో ఏది ఉపయోగించబడింది? దయచేసి అన్ని తగిన ఆప్షన్ లను చెక్ చేయండి. (రైతు/కాంట్రాక్టర్)

- ☐ నత్రజని- ఫాస్ఫరస్- పొటాషియం ఆధారిత ఎరువులు (అంటే, ఎన్ పికె)
- ☐ జింక్ ఆధారిత ఎరువులు
- ☐ సహజ ద్రవ ఎరువులు (జీవమృత్)
- ☐ వెర్మీ కంపోస్ట్
- ☐ యూరియా
- ☐ సూపర్ (ఫాస్ఫరస్, సల్ఫర్ మరియు కాల్షియం ఆధారిత ఎరువు)
- ☐ ఇతరులు - దయచేసి ___ పేర్కొనండి.

46) 2020 మరియు 2021 లో తరువాత నెలల్లో ప్రతి ఎరువుల రకాన్ని తోటవద్ద ఉపయోగించిన నెలలను దయచేసి పేర్కొనండి?

	నత్రజని-ఫాస్ఫరస్-పొటాషియం ఆధారిత ఎరువులు		జింక్ ఆధారిత ఎరువులు		సహజ ద్రవ ఎరువులు (జీవమృత్)		వెర్మీ కంపోస్ట్		యూరియా		సూపర్ (ఫాస్ఫరస్, సల్ఫర్ మరియు కాల్షియం ఆధారిత ఎరువు)		ఇతరులు ___________ _______	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
జనవరి														
ఫిబ్రవరి														
మార్చి														
ఏప్రిల్														
మే														
జూన్														
జులై														
ఆగస్ట్														

సెప్టెంబర్														
అక్టోబర్														
నవంబర్														
డిసెంబర్														

47) 2021లో మీ తోటలో ఉపయోగించే ప్రతి ఎరువుల రకానికి వార్షిక ఖర్చు ఎంత?

ఉపయోగించే ఎరువులు	**ఎరువుల వార్షిక ఖర్చు (రూపాయల్లో)**
నత్రజని- ఫాస్పరస్- పొటాషియం ఆధారిత ఎరువులు (అంటే, ఎన్ పికె)	
జింక్ ఆధారిత ఎరువులు	
సహజ ద్రవ ఎరువులు (జీవమృత్)	
వెర్మీ కంపోస్ట్	
యూరియా	
సూపర్ (ఫాస్ఫరస్, సల్ఫర్ మరియు కాల్షియం ఆధారిత ఎరువు)	
ఇతరులు- దయచేసి specify__________________	

48) మీ తోటలోని మామిడి చెట్లను ఎక్కువగా ప్రభావితం చేసే వ్యాధులను దయచేసి పేర్కొనండి? దయచేసి అన్ని తగిన బాక్సులను చెక్ చేయండి.

	ఆంత్రాక్నోస్		గమ్మోసిస్
	కాండం చివర కుళ్ళిపోతుంది		స్కేలు
	నల్ల కుళ్లు		బ్లాక్-బ్యాండెడ్
	పౌడర్లీ మిల్డ్యూ		గనోడెర్మా వేరు కుళ్ళిపోతుంది
	తిరిగి మరణించండి		రూట్ కుళ్ళిపోవడం మరియు డ్యాంపింగ్ ఆఫ్
	మసి బూజు		ఎరుపు తుప్పు
	ఫోమా బ్లైట్		లిచెన్స్
	బాక్టీరియల్ కాంకర్		దుర్వాప్రేమేషన్
	దోమ		
	ఇతరులు - దయచేసి ____ పేర్కొనండి.		

49) 2021లో మీ తోటలో ఈ క్రింది వాటిలో ఏ పురుగుమందులు ఉపయోగించబడ్డాయి? దయచేసి అన్ని తగిన ఆప్షన్ లను చెక్ చేయండి.

☐ వేప నూనె పిచికారీ

☐ వేప గింజల పొడి

☐ శిలీంధ్రనాశిని

☐ యూరియా

☐ ఇతరులు - దయచేసి ____ పేర్కొనండి.

50) 2020 మరియు 2021 లో తరువాత నెలల్లో పండ్ల తోటలో ఉపయోగించే ప్రతి పురుగుమందుల రకం యొక్క పరిమాణాన్ని (కిగ్రాలలో) దయచేసి పేర్కొనండి?

	వేప నూనె పిచికారీ	వేప గింజల పొడి	శిలీంధ్రనాశిని	యూరియా	ఇతరులు __________

	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
జనవరి										
ఫిబ్రవరి										
మార్చి										
ఏప్రిల్										
మే										
జూన్										
జులై										
ఆగస్ట్										
సెప్టెంబర్										
అక్టోబర్										
నవంబర్										
డిసెంబర్										

51) 2021లో మీ తోటలో ఉపయోగించే ప్రతి పురుగుమందుల రకం యొక్క వార్షిక ఖర్చు ఎంత?

ఉపయోగించే పురుగుమందు	**పురుగుమందుల ఖర్చు (రూపాయల్లో)**
వేప నూనె పిచికారీ	
వేప గింజల పిచికారీ	
శిలీంధ్రనాశిని	
యూరియా	
ఇతరవి- దయచేసి ____ పేర్కొనండి.	

52) 2021 సంవత్సరంలో దిగువ పేర్కొన్న దానికి మీ వార్షిక ఖర్చు ఎంత?

	(రూపాయల్లో)
కూలీ	
నీటిపారుదల	
పవర్ (విద్యుత్)	

53) మీ తోటలో ఈ క్రింది వాటిలో ఏ నీటిపారుదల పద్ధతులను ఉపయోగిస్తారు? దయచేసి వర్తించే అన్ని బాక్సులను చెక్ చేయండి.

☐ బేసిన్ విధానం ☐ స్ప్రింక్లర్ సిస్టమ్

☐ ఫర్రో పద్ధతి ☐ ఇతరులు - దయచేసి ____ పేర్కొనండి.

☐ డ్రిప్ సిస్టమ్

54) 2020 మరియు 2021 లో ప్రతి తరువాతి నెలల్లో సుమారు రోజుల సంఖ్యను దయచేసి సూచించండి, ఈ సమయంలో పైప్డ్ నీటి సరఫరాను ఉపయోగించి మీ తోటకు సాగునీరు అందించబడింది.

	జనవరి	ఫిబ్రవరి	మార్చి	ఏప్రిల్	మే	జూన్	జూలై	ఆగస్ట్	సెప్టెంబర్	అక్టోబర్	నవంబర్	డిసెంబర్
20 20												
20 21												

55) 2020 లో ప్రీహార్వెస్ట్ ఫాల్ (అంటే, పుష్పించిన తరువాత మరియు కోతకు ముందు కోల్పోయిన మొత్తం ఉత్పత్తి) కారణంగా మీ తోటలో కోల్పోయిన మామిడి పండ్ల యొక్క సుమారు శాతం (విక్రయించే మామిడి పండ్ల వార్షిక గణన ఆధారంగా) ఎంత? దయచేసి అత్యంత సముచితమైన బాక్స్ చెక్ చేయండి.

☐ 0 నుంచి 5% ☐ కంటే తక్కువ 5 నుంచి 10% ☐ 10 నుంచి 15% కంటే తక్కువ

☐ 15 నుంచి 20% ☐ కంటే తక్కువ 20 నుంచి 25% ☐ కంటే తక్కువ 25 నుంచి 30% కంటే తక్కువ

☐ 30 నుంచి 35% ☐ కంటే తక్కువ 35 నుంచి 40% ☐ కంటే తక్కువ 40 నుంచి 45% కంటే తక్కువ

☐ 45 నుంచి 50% ☐ కంటే తక్కువ 50 నుంచి 55% ☐ కంటే తక్కువ 55 నుంచి 60% కంటే తక్కువ

56) 2021లో ప్రీహార్వెస్ట్ ఫాల్ (అంటే, పుష్పించిన తరువాత మరియు కోతకు ముందు కోల్పోయిన మొత్తం అవుట్ పుట్) వల్ల మీ తోటలో కోల్పోయిన మామిడి పండ్ల యొక్క సుమారు శాతం ఎంత ? దయచేసి అత్యంత సముచితమైన బాక్స్ చెక్ చేయండి.

☐ 0 నుంచి 5% ☐ కంటే తక్కువ 5 నుంచి 10% ☐ 10 నుంచి 15% కంటే తక్కువ

☐ 15 నుంచి 20% ☐ కంటే తక్కువ 20 నుంచి 25% ☐ కంటే తక్కువ 25 నుంచి 30% కంటే తక్కువ

☐ 30 నుంచి 35% ☐ కంటే తక్కువ 35 నుంచి 40% ☐ కంటే తక్కువ 40 నుంచి 45% కంటే తక్కువ

☐ 45 నుంచి 50% ☐ కంటే తక్కువ 50 నుంచి 55% ☐ కంటే తక్కువ 55 నుంచి 60% కంటే తక్కువ

57) అధికంగా పండిన పండ్లు లేదా పాడైపోయిన లూజ్ ఫ్రూట్ వల్ల అమ్మకానికి ముందు కోత నష్టం యొక్క సుమారు % సీజన్ కొరకు కోత కు గురైన మొత్తం పరిమాణంలో ఒక శాతంగా దయచేసి పేర్కొనండి.

% ప్రీ సేల్ హార్వెస్ట్ నష్టం

☐ 0 నుంచి 2% ☐ కంటే తక్కువ 2 నుంచి 4% ☐ కంటే తక్కువ 4 నుంచి 6% కంటే తక్కువ

☐ 6 నుంచి 8% ☐ కంటే తక్కువ 8 నుంచి 10% ☐ 10 నుంచి 12% కంటే తక్కువ

☐ 12 నుంచి 14% ☐ కంటే తక్కువ 14 నుంచి 16% ☐ కంటే తక్కువ 16 నుంచి 18% కంటే తక్కువ

☐ 18 నుంచి 20% ☐ కంటే తక్కువ 20 నుంచి 22% ☐ కంటే తక్కువ 22 నుంచి 24% కంటే తక్కువ

58) 2020 మరియు 2021 సంవత్సరాల కోత కాలంలో మీరు మామిడి పండ్లను ఎన్నిసార్లు ఎంచుకున్నారు? దయచేసి తగిన బాక్సులను తనిఖీ చేయండి.

	1	2	3	4	5
2020					
2021					

59) ఒక రోజు మామిడి పండ్లను ఎంచుకోవాలా వద్దా అనే దానిపై మీ నిర్ణయంలో దిగువ పేర్కొన్న ఏ సమస్యలు కారణం? దయచేసి వర్తించే అన్ని బాక్సులను చెక్ చేయండి.

☐ కోతకు కావలసిన తేదీ నాటికి కాయ యొక్క గణనీయమైన పరిమాణం కావలసిన పరిపక్వత స్థాయిలో ఉంటుంది

☐ ఆశించిన కోత తేదీ నాటికి పండ్ల యొక్క గణనీయమైన పరిమాణం పెద్ద పరిమాణంలో ఉంటుంది

☐ ఆశించిన కోత తేదీ నాటికి భూమిపై గణనీయమైన పరిమాణంలో అధికంగా పండిన లేదా దెబ్బతిన్న వదులుగా ఉన్న పండ్లు కనిపిస్తాయి

☐ కార్మిక లభ్యత

☐ రవాణా లభ్యత

☐ నిల్వ లభ్యత

☐ మార్కెట్ రేటు

☐ ఆసన్న వాతావరణ పరిస్థితుల కారణంగా నష్టాన్ని పరిహరించండి (అంటే, భారీ వర్షపాతం లేదా అధిక గాలి వేగాలకు ఏదైనా సూచనకు ముందు కోతకు)

☐ ఇతరవి - దయచేసి ___ పేర్కొనండి.

60) మీ తోటపై ఉండే ప్రతి పికింగ్ సైకిల్ ఆధారంగా దయచేసి దిగువ పేర్కొన్నవి పేర్కొనండి.

	పికింగ్ 1	పికింగ్ 2	పికింగ్ 3	పికింగ్ 4	పికింగ్ 5
కోత జరిగిన నెల వారం					
కోతలో ఏదైనా ఆలస్యం మీరు అనుభూతి చేశారా (అవును/కాదు)					
ఒకవేళ అవును అయితే, ఎన్ని రోజులు ఆలస్యం?					
ఆలస్యానికి ప్రాథమిక కారణం (మీరు కోరుకున్న రోజున కోత కురాలేకపోయినప్పుడు మాత్రమే వర్తించే అన్ని బాక్సులను దయచేసి తనిఖీ చేయండి - లేనిపక్షంలో, ఆ పికింగ్ సైకిల్ కొరకు అన్ని బాక్సులను	☐కార్మిక లభ్యత ☐రవాణా లభ్యత ☐నిల్వ లభ్యత ☐మార్కెట్ రేటు ☐వాతావరణ పరిస్థితులు	☐కార్మిక లభ్యత ☐రవాణా లభ్యత ☐నిల్వ లభ్యత ☐మార్కెట్ రేటు ☐వాతావరణ పరిస్థితులు ☐ఇతర ________	☐కార్మిక లభ్యత ☐రవాణా లభ్యత ☐నిల్వ లభ్యత ☐మార్కెట్ రేటు ☐వాతావరణ పరిస్థితులు	☐కార్మిక లభ్యత ☐రవాణా లభ్యత ☐నిల్వ లభ్యత ☐మార్కెట్ రేటు ☐వాతావరణ పరిస్థితులు	☐కార్మిక లభ్యత ☐రవాణా లభ్యత ☐నిల్వ లభ్యత ☐మార్కెట్ రేటు ☐వాతావరణ పరిస్థితులు

చెక్ చేయకుండా విడిచిపెట్టండి)	☐ఇతర ________		☐ఇతర ________	☐ఇతర ________	☐ఇతర ________

61) మీ కోత వేలం వేయబడిన సేకరణ కేంద్రాన్ని దయచేసి పేర్కొనండి.

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62) మీ తోట నుండి సేకరణ కేంద్రానికి సుమారుగా ఎంత దూరం?

- ☐ 20 కిలోమీటర్ల కంటే తక్కువ
- ☐ 20 నుంచి 40 కి. మీ.
- ☐ 40 నుంచి 60 కి. మీ.
- ☐ 60 నుంచి 80 కి. మీ.
- ☐ 80 నుంచి 100 కిలోమీటర్లు
- ☐ 100 నుంచి 120 కి. మీ.
- ☐ 120 నుంచి 140 కి. మీ.
- ☐ 140 కిలోమీటర్లకు పైగా

63) 2021 సంవత్సరానికి వరుసగా ప్రతి పికింగ్ సైకిల్ కొరకు మార్కెట్ లో విక్రయించే మామిడి పండ్ల యొక్క పరిమాణ వివరాలను దయచేసి పేర్కొనండి.

		పికింగ్ 1	పికింగ్ 2	పికింగ్ 3	పికింగ్ 4	పికింగ్ 5
రాకమ్ 1 ________	మొత్తం మామిడి పండ్ల పరిమాణం					
	మామిడి పండ్లు సైజుద్వారా సార్ట్ చేయబడ్డాయా (అవును/కాదు)					
	ఒకవేళ అవును అయితే, చిన్న సైజు మామిడి పండ్ల పరిమాణం					
	ఒకవేళ అవును అయితే, మధ్యస్థ మరియు పెద్ద సైజు మామిడి పండ్ల పరిమాణం					

		పికింగ్ 1	పికింగ్ 2	పికింగ్ 3	పికింగ్ 4	పికింగ్ 5
రాకమ్ 2 ________	మొత్తం మామిడి పండ్ల పరిమాణం					
	మామిడి పండ్లు సైజుద్వారా సార్ట్ చేయబడ్డాయా (అవును/కాదు)					

	ఒకవేళ అవును అయితే, చిన్న సైజు మామిడి పండ్ల పరిమాణం					
	ఒకవేళ అవును అయితే, మధ్యస్థ మరియు పెద్ద సైజు మామిడి పండ్ల పరిమాణం					

64) 2021 సంవత్సరానికి గాను ప్రతి పికింగ్ సైకిల్ కొరకు మార్కెట్ లో ఉత్పత్తి చేయబడ్డ మరియు విక్రయించబడ్డ మామిడి పండ్ల యొక్క ధర వివరాలను దయచేసి పేర్కొనండి.

		పికింగ్ 1	పికింగ్ 2	పికింగ్ 3	పికింగ్ 4	పికింగ్ 5
రాకమ్ 1 ________	మామిడి పండ్ల కొరకు అందుకున్న మొత్తం ధర					
	చిన్న సైజు మామిడి పండ్లకొరకు అందుకున్న ధర					
	మధ్యస్థ మరియు పెద్ద సైజు మామిడి పండ్ల కొరకు అందుకున్న ధర					

		పికింగ్ 1	పికింగ్ 2	పికింగ్ 3	పికింగ్ 4	పికింగ్ 5
రాకమ్ 2 ________	మామిడి పండ్ల కొరకు అందుకున్న మొత్తం ధర					
	చిన్న సైజు మామిడి పండ్లకొరకు అందుకున్న ధర					
	మధ్యస్థ మరియు పెద్ద సైజు మామిడి పండ్ల కొరకు అందుకున్న ధర					

65) ప్రతి పికింగ్ సైకిల్ కొరకు దయచేసి లేబర్ మరియు రవాణా వివరాలను పేర్కొనండి.

	పికింగ్ 1	పికింగ్ 2	పికింగ్ 3	పికింగ్ 4	పికింగ్ 5
ఉపయోగించిన కార్మికుల సంఖ్య					
ప్రతి కార్మికుడికి సగటు వేతనం (రోజుకు)					
రవాణా ఖర్చు					