IDENTIFICATION OF THE SCOPE OF INFORMATION TECHNOLOGY INTERVENTION IN HORTICULTURE IN THE POST COVID WORLD – A THEMATIC ANALYSIS APPROACH

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Abstract

The COVID-19 pandemic has impacted the agriculture industry across the world. Agricultural activities are time-bound and, the impacts of the COVID-19 on agriculture are currently under scrutiny. COVID-19 has also changed the dominant discourses in agricultural research. This study seeks to understand the dominant discourses in the impact of COVID-19 on agriculture and aims to identify the potential avenues of information technology interventions.

This research study uses a qualitative research method, i.e., thematic analysis. In this research, peer-reviewed research articles are predominantly used as secondary data. Various themes and sub-themes that emerged from these research articles are classified into four main themes: (1) Farmer lockdown experience; (2) Horticulture, Digital transformation and COVID-19; (3) Low productivity and urgent need of technology adoption; (4) Other themes

This research finds the dominant discourses in the horticulture sector during the COVID-19 pandemic and how information technology intervenes to meet and or control these challenges. The results from the research will contribute to our understanding of information technology responses to disruptions.

Keywords: *COVID-19, horticulture, food supply, online buying, labour shortage*

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Amrik Chand

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Chapter 1 : Introduction

1.1 Introduction

Various pandemics that humanity experienced in the past, such as Spanish Flu, Asian Flu, Hong Kong Flu, Ebola and Swine Flu, have placed an unprecedented burden on the world economy and global health system. In March 2020, the transmission of the new coronavirus had significantly affected the agriculture industry (Di Vaio et al., 2020). During global lockdowns, the agriculture industry faced numerous challenges. For example, many Northern and Southern hemisphere countries faced a labour crisis as border restrictions curtailed the supply of agricultural labourers (Neef, 2020). Strict border controls and internal lockdowns created delays in providing agricultural inputs like seeds and pesticides, causing further disruption to the agricultural supply chain (Richards & Rickard, 2020; Zhang et al., 2021). Due to the COVID-19 lockdown decision by the government, every business included schools, restaurants etc. were closed. This adversely affects food growers and distributors. During the pandemic, they shift their supplies from food service to food retailers (Richards & Rickard, 2020, p. 190).

Greenville et al. (2020) indicate that the horticulture sector's modern strategic and management techniques put pressure on the global market to develop and modify the agriculture system to meet problems posed by pandemics such as COVID-19 (p. 5). In the agriculture sector, the production and processing processes have been significantly industrialized and modernized. As a result, the sector urgently needs to adopt new technology and advanced processes in order to compete in the global market (Bakalis et al., 2020, p. 167). Within the last decade, the agriculture sector has undergone rapid change, with the use of modern techniques and tools in the agricultural production process. This pandemic serves as a catalyst for the industry to adopt and cope with the digitalisation of the agricultural process to combat similar pandemics in the future (Shepherd et al., 2020).

Given the agricultural disruptions caused by the COVID-19 pandemic, this research seeks to understand the dominant discourses in studying COVID-19 impacts on horticulture. It also aims to identify the potential areas where information technology interventions can help meet the challenges of the horticulture industry. Before proceeding with the research, I will briefly explain the meaning of the terms 'agriculture' and 'horticulture,' as they are used in this study.

According to Tanjuakio et al. (1996), there are two dominant definitions of agriculture. The first definition conceptualises agriculture as the “food and fibre” sector. The second depicts agriculture as a “farm and farm-related” industry (p.47). Both conceptualisations include the horticulture industry. Horticulture is the focus of this study, and the term "agriculture" is also used to refer to horticultural activities. Horticulture can be broadly defined as an integrated activity concerning different agricultural organisations and associations, various sector-specific procedures, special environmental conditions, and unique skilled labour requirements. (Bochtis et al., 2020, p. 2).

1.2 Research Gap

Numerous studies have examined the impact of the COVID-19 pandemic on agriculture (Bakalis et al., 2020; Bank, 2020; Bochtis et al., 2020; Greenville et al., 2020; Healy et al., 2020; Kim et al., 2020; Neef, 2020; Ramakumar, 2020; Saha & Bhattacharya, 2020; Shrestha et al., 2020; Shruthi & Ramani, 2020; Smith & Wesselbaum, 2020). For example, the impact of COVID-19 on agricultural commodity prices is a widely discussed theme.

According to Shruthi and Ramani (2020) the global lockdown during COVID-19 hampered the availability of agriculture inputs, driving up the cost of horticulture production inputs, resulting in agricultural commodity inflation. This indicates how agricultural production inputs, and the agrarian market are inextricably linked. Similarly, researchers are keen to understand the transformation of the agricultural market after the COVID-19 pandemic (Bank, 2020).

According to the Bank (2020), the post COVID-19 agro-industrial strategy in the Southeast Asian countries focuses on the use of science-based data, interventions that are the agriculture market mechanisms oriented. There is also research effort towards understanding the impacts of COVID-19 on the food systems (Bakalis et al., 2020; Healy et al., 2020).

As Healy et al., (2020) discussed, the government's strict pandemic response prioritized human health, but it undermined the country's food system, from production to manufacturing and processing to distribution, accessibility, availability, and consumption. The general population's panic buying and storing of durable foods like pasta, flour, beans, and rice has had an enormous effect on the food system (Serafim et al., 2020).

Smith and Wesselbaum (2020) discussed in their study that the number of individuals with low nutrition would increase from 690 million to 820 million by 2020, underscoring the urgent need to change the agricultural system to address the issues of malnutrition. The COVID-19 situation has forced researchers to critique the link between food security and pandemics.

Another important theme relates to the workforce shortage caused by the COVID-19 pandemic (Bochtis et al., 2020; Neef, 2020).

In the last two decades, governments in North America, Europe, and Australasia have established a set of programmes to ensure a steady supply of migrants to meet labour shortages in the agricultural industry (Neef, 2020). Bochtis et al. (2020) explain how during COVID-19, countries begin closing their borders that resulted in restrictions on farm workers' mobility and the subsequent labour shortage.

Vegetable and fruit growers, as well as garden nurseries have been most affected by the labour shortages. The COVID-19 pandemic has prompted a rethinking of agriculture's role in society. Several studies, for example, have identified the critical role those agricultural workers play in society, as well as their "undeniably essential" nature (Neef, 2020).

1.3 Problem Statement and Research Questions

Information systems research has extensively studied the relationship between information technology and agriculture (Banker et al., 2011). The impact of COVID-19 disruption on agriculture has also been extensively researched, and studies have been conducted on the impact of COVID-19 on agricultural research (Shrestha et al., 2020). For example, one study presents how the pandemic has changed the research discourses about agriculture and that "resilience" seems to precede "efficiency" in the post COVID-19 world (Bakalis et al., 2020). COVID-19 studies have also suggested that investments in agricultural research "generate higher returns and is a far superior method" for addressing issues of sustainability (Bank, 2020, p. 12). This study will contribute to the existing body of research on the impact of COVID-19 on agriculture and will help find avenues where information technology address can intervene. Scholars have also emphasised the urgent need for meaningful synthesis of literature and theories in agriculture Digitisation, applied policies and agriculture research (Pannell & Claassen, 2020). This research study addresses two questions below:

- What are the dominant discourses in the study of the impacts of COVID-19 on horticulture?
- What are the potential areas of information technology interventions in horticulture in the post COVID world?

1.4 Significance and Expected Contribution of the Study

The COVID-19 had a significant impact on all sectors of the economy. It is currently complicated to determine the precise consequences of this pandemic on the horticulture sector. This study can look into the various challenges that the sector faced at the time. What role does technology play in addressing these issues in the post-COVID era? This study will add to the existing body of knowledge about the need for, role of, and benefits of technology assistance in the horticulture sector during the current crisis and in the future to deal with these types of disruptions.

1.5 Organisation of Dissertation

The dissertation is composed of six chapters. Chapter 1 is an introduction to the research and presents the background of the study along with the research questions. Chapter 2 provides a review of previous studies on the impact of COVID-19 on horticulture and what potential areas of information technology interventions in horticulture in the post-COVID period. The third chapter expands on the research method and explains how the thematic analysis was used to identify various themes related to horticulture and information technology. Chapter 4 provides a more in-depth examination of the themes' interrelationships and identifies potential avenues for information technology interventions. Chapter 5 is the discussion; this chapter discusses and develops a framework for identifying the potential areas of IT intervention. Chapter 6 is the Conclusion section that summarises the implications of the research, its theoretical contribution, the limitations, and possible directions for future research.

Chapter 2 : Research Method

2.1 Introduction

This chapter introduces the methods of data collection and analysis used in this research. This research falls under the paradigm of qualitative research as it uses *words* - as data and utilises a meaning-based from data analysis (Braun & Clarke, 2013). It acknowledges the subjectivity of the researcher in the process.

2.2 Choice of Qualitative Research

I chose a qualitative research approach for this study because it does not necessitate the prior selection of variables (Cavaye, 1996) and is well suited to study the role of context (Myers, 2009). Another reason for employing a qualitative approach was to gain a thorough understanding of the literature, which assisted me in investigating the perspectives of horticultural stuff (Polit & Beck, 2012), identify critical difficulties, and further, the field's existing theory that is relevant to the study's objectives. Thematic analysis was used to analyse the content of the information technology and COVID-19, contemporary information system, and experience of the horticulture sector during this unprecedented time around the world.

This thematic review aims to identify, analyse, and report on the important topics in the literature about the horticultural sector's experience with information technology, particularly during the COVID-19 epidemic (Braun & Clarke, 2006). The benefit of a thematic analysis is as follow: (a) it can be applied across the different theoretical approaches, potentially facilitating new, rich, detailed, and complex understanding of the data (Braun & Clarke, 2006). (b) Regional boundaries do not limit the data analyses because that is based on thematic analysis of literature rather than interviews or focus groups. (c) Thematic analysis is flexible because it allows the researcher to discover themes using a wide range of ways. I have chosen to undertake a thematic analysis to explore emergent themes and patterns across horticulture, information technology and COVID-19. As a result, our research has the potential to find new facts and provide a comprehensive understanding of this vital topic. No statistical analysis of the data has been done in this research and that is the reason for not using the meta-analysis in this research. Systematic literature review provides stronger evidence with the fewer articles when compared to the other reviews (Bryman, 2011).

Transcripts of Interviews and other interview-related media, such as surveys, essays, and video recordings, have focused on thematic analysis (Joffe & Yardley, 2004). Thematic analysis is

also widely used to analyse published literature as it provides rigour to the study and helps in the analysis of complicated relationships (Thomas & Harden, 2008).

2.3 Thematic Analysis Process

In this dissertation, we will use thematic analysis described by Braun and Clarke (2006) as "a method for identifying, analysing and reporting patterns (themes) within data." (p. 79). According to Greg Guest et al. (2012), thematic analysis is a qualitative method for generating codes from raw data. The researcher reads and re-reads the data to find specific themes that are deemed critical to answering the research questions. The analytic process for this study was driven by Braun and Clarke (2006) six phases of thematic analysis (as shown in Table) to identify and describe patterns or themes within the data.

Table 2.1 *Doing Thematic Analysis: A Step-by-Step Guide*

Phase 1	Read journal papers, search for agriculture, COVID-19, and information technology, words and familiarize me with it.
Phase 2	We are producing codes that are relevant to the research question. Such as 'COVID-19', 'agriculture industry', 'technology adoption and challenges' Also, search databases for journal articles using these codes.
Phase 3	In the third phase, start grouping the same themes, ideas, and trends to answer the research question.
Phase 4	Evaluate the themes
Phase 5	We are defining the themes and naming themes based on the literature.
Phase 6	Analysing the data and discussing the findings.

2.3.1 Phase 1: Familiarizing yourself with the data

As secondary data is used for this study, according to Braun and Clarke (2006), the researcher needs to familiarise themself with the depth of the topic by reading and re-reading the material in a concentrated and active way to find out the exact meaning, patterns, data and so on.
The first and most crucial component of this phase of the research is to identify the literature that will be examined to answer the research questions, followed by a study of the literature collected to become acquainted with the overall scope of the data. I found that the time spent reading the literature was very useful, as it began to inform the early stages of analysis in

becoming familiar with the data. I used the AUT's online library databases to find relevant articles for this study, specifically Business Source Complete (EBSCOhost), Scopus, Web of Science, and Google Scholar. The reason for selecting these four databases is their massive collection of research articles focusing on various disciplines, including business and information system research.

The examples of the keywords that I used for searching the literature are as shown in the table below:

Table 2.2 *Keywords Used for Finding Literature*

horticultur*	COVID-19 Agri Futures
COVID-19 and Food and Fibre sector	Food supply
Panic buying	COVID-19 and Smart agriculture
Agri-business	Agricultural marketing
Agriculture	Online grocery delivery
Fruit and Vegetables	Agri-food industry
Alternate systems of farming	Government's restriction

After the search results, the next step is to scrutinise each article to understand whether the content relates to a research topic. The irrelevant research articles were screened out by reading the title and abstract of the article based on some criteria such as (a) Article does not talk about the agriculture or horticulture, and COVID-19 (b) applied filter in library database for the date range December 2019 to July 2021 (c) only peer reviewed research articles. These all steps followed to get the high standard published research articles.'

By applying the criteria mentioned above, 212 articles were selected from four different databases: Scopus or EBSCO, web of science, and Google Scholar. Some of the research articles find as duplicated in the database so 162 finalise at this stage of the research.

In the next phase by keeping the scope of the research in mind the list of articles was further screen out by reading the full text. The final articles that I select to find out themes must have at least one of the features out of these there (a) COVID -19 impact on the agriculture output (b) agriculture marketing strategies during COVID-19 (c) skill labour shortage etc. By keeping these inclusion criteria in mind. Finally, 52 research articles were selected to familiarise with the data to find out the codes for the next phase of thematic analysis.

Figure 2.1 *Flowchart Illustrating the Process of Finding and Selecting Relevant Articles*

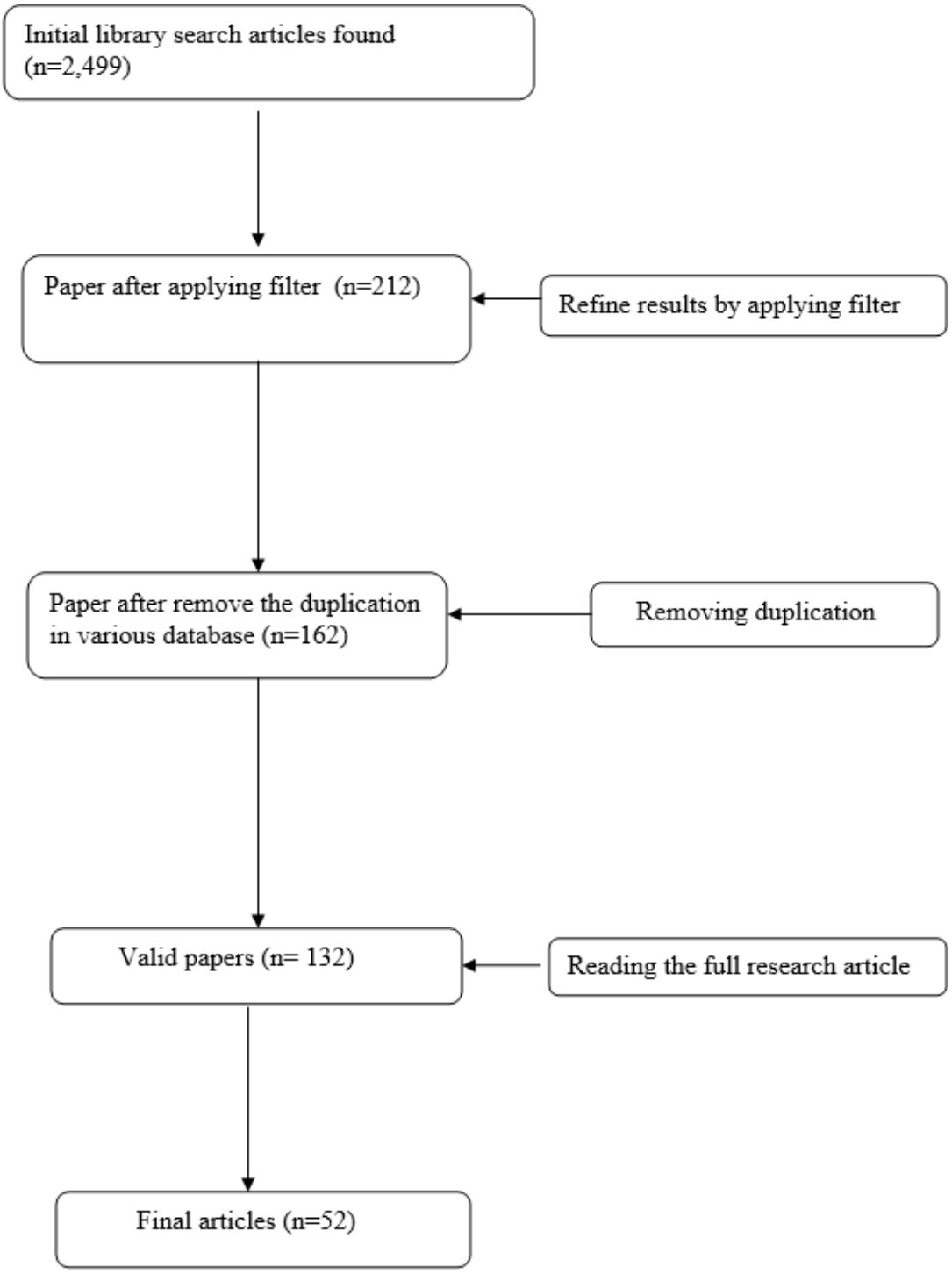


Table 2.3 *Few Examples of Finding Initial Codes from Selected Research Articles*

Author (Year)	Title of Research Paper	Initial codes
Neef, A. (2020)	*Legal and social protection for migrant farm workers: lessons from COVID-19*	• Labour shortage in COVID-19 • health check on workplace • COVID-19 guideline for safe workplace.
Agyei et al., (2021)	*COVID-19 and food prices in sub-Saharan Africa*	• Food inflation COVID-19 and food security • COVID-19 disturb the food supply system.
Ben Hassen et al., (2020)	*Impact of COVID-19 on Food Behavior and Consumption in Qatar*	• panic for stockpiling the food during COVID-19
Shruthi & Ramani, (2020)	*Statistical analysis of impact of COVID 19 on India commodity markets*	• Farm agriculture inputs shortage • Cost of production increased during pandemic.

After reading the final research articles, I understand the raw data on the COVID pandemic effects on the horticulture sector. As shown above in the Table 3 initial codes emerged from the articles. All of the others selected research articles are detailed in the attached Annexure. In addition, an initial list of coding and other interesting characteristics was prepared in order to prepare for the next steps at the end of this phase

2.3.2 Phase 2: Generating initial codes

Braun and Clarke (2016) suggest Phase 2 begins when the researcher involves "reducing the text into manageable and meaningful text segment" and involves a process known as coding. Coding highlights an item of data and assigning it a label or code name that best describes its contents, thus analysing and synthesizing, meaningful part of data to determine how it linked to the research question.

When analysing the data, the researcher highlighted and coded everything that was noteworthy or potentially interesting.

Figure 2.2 *Initial Code of Step 1*

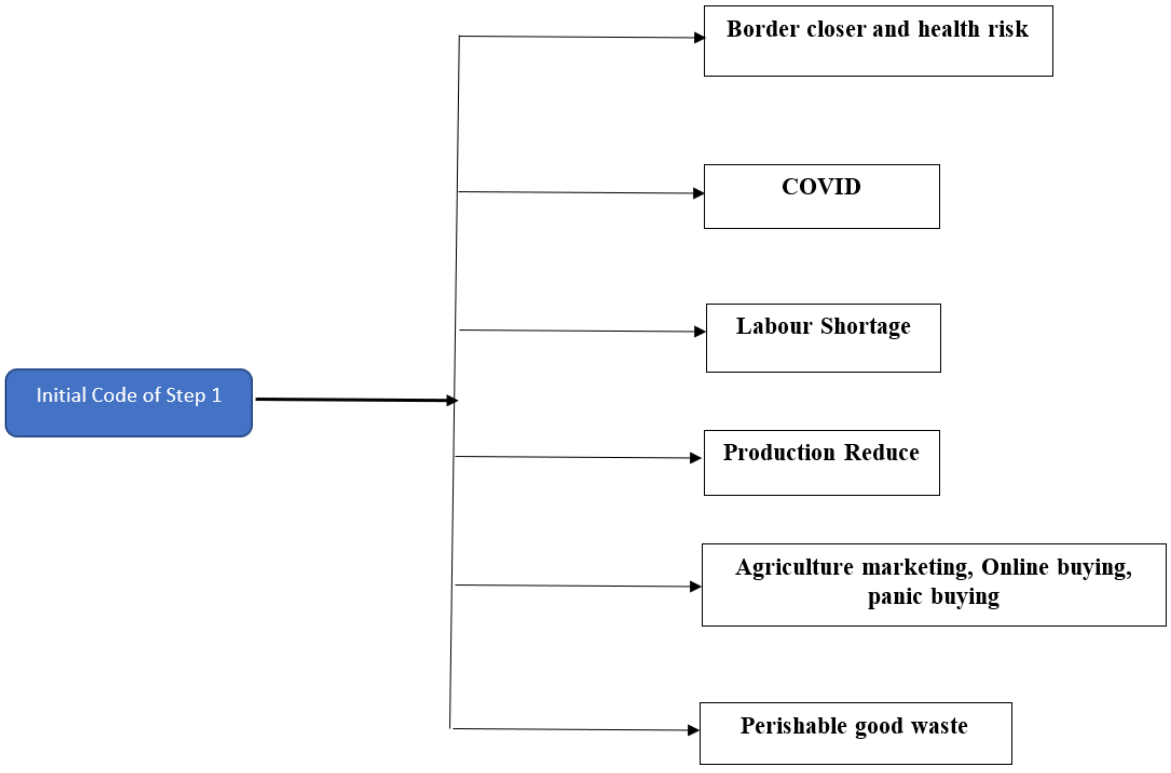
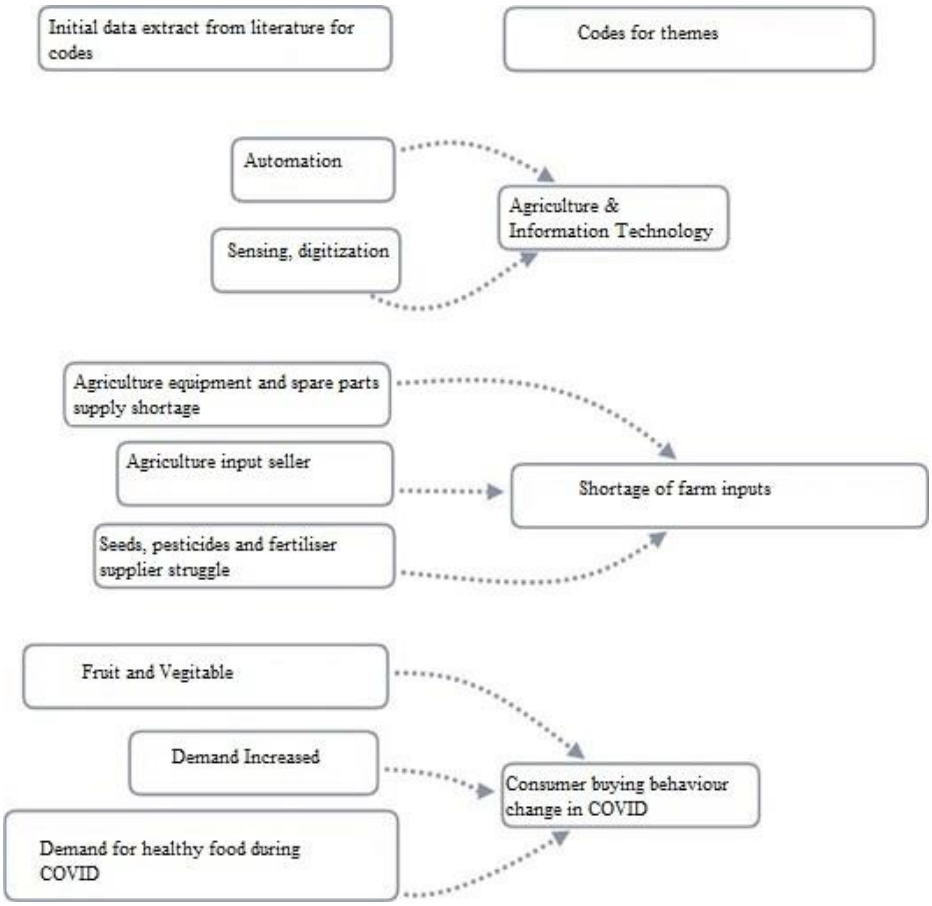


Figure 2.3 *Code Applied to the Data extract from Literature*



At this stage, the coding was at its initial process and flexible, which meant that the researcher could create as many codes as he or she wanted, and one data extract could fit into multiple codes. for example, Decode "agriculture and information technology" that I excerpt from the "*Cherry tomato production in intelligent greenhouses-sensors and AI for control of climate, irrigation, crop yield, and quality*." Hemming et al. (2020). By reading some ideas on digital sensor and automation. In the research article data (words) expressed that How technology can help improve crop production settings by collecting the data on irrigation and climate. After reading this research article I generated the initial codes: "*automation", "digitisation"*. Annexure provides the initial codes that I generated for each research paper. Following that, all of the initial codes were grouped based on their commonalities, laying the groundwork for

the next phase of emerging themes. This stage resulted in a list of specific codes detailing how the data contributed to the research to find the solution of research questions. The Figure 2 the some of the codes from the research articles, By doing this rigorous process on selected research articles I find several Codes. From theses Codes I finalised eight sub themes and four main these which are relevant to this research study. Some examples of these Codes, sub-themes are as in the figure below:

2.3.3 Phase 3: Searching for themes

Phase 3 generally begins when all data have been initially coded and collected (Braun & Clarke, 2006). The researcher now has a comprehensive list of the different codes found across the research articles. The identification of comparable themes and sub-themes is the goal at the end of this stage. The researcher started by analysing principles that were identified and developed in phase 2 and thinking about how different codes may be linked to form potential themes (Boyatzis, 1998; Braun & Clarke, 2006). In this research the themes selection process was done manually.

This is the stage of the research where the researcher began to consider the links between different level of themes and sub themes, as some codes went on to form main themes, where others formed sub-themes. A group of codes were also rejected as they did not fit into any of the themes or sub themes. Identifying themes, according to Attire-Stirling (2001), is a complex process that needs high attention to detail and flexibility, as emerging themes frequently need to be re-worked to fit new codes.

2.3.4 Phase 4: Reviewing themes

According to Braun and Clarke (2006), phase 4 begins after the researcher has chosen and begun to refine the themes and sub-themes (p. 91). The literature is being reviewed through themes rather than chronological order during this research phase and identifying whether they formed a logical pattern. Some of the themes were rejected because there was insufficient data to support them, the data was too diverse, or research papers were not fit for the purpose of this research study. One of the research articles I read, for example, was about the COVID-19, the global food system, and wellbeing. One theme appeared from the COVID-19, food system and household welfare heading, however reading the research article in detail revealed that it was out of context for this research study. The article more talk about the economic policies implication varying during the time of COVID-19. So, in the end exclude that theme from my

main theme list. The researcher also considered whether some themes could be combined into a single theme whether they needed to be separated into several themes (Braun & Clarke, 2006).

The major goal of this stage is to recheck and refine the primary themes that have been identified. The researcher reads all the material extracted at the code level in the first stage; then determines the validity of that theme concerning the data set, existing theoretical concepts and ideas, and the research question in the second step (Braun & Clarke, 2006; Thomas & Harden, 2008).

2.3.5 Phase 5: Defining and naming themes

In this phase the research must satisfactorily draw the thematic map of the data. At this point, the researcher defines and further refine the themes they find and analyses the data within them. By 'define and refine' the author means identifying the 'essence' of what each theme is about and determining what aspect of the data each theme captures. In this phase, the researcher finds out what is interesting about the data and why, as the researcher needs to find out how each theme will fit into the overall 'story' that will help find out the solution to the dissertation's research question. In this phase the researcher had a reliable, detailed analysis of how the themes contributed to understanding the data and research questions. The themes were polished and re-defined once more to further explain their view in response to the research topic.

According to Braun and Clark, by the end of this phase, the research will be able to find out which themes are significant for this research and why by summarizing the scope and content of each theme in few sentences. This will identify if any further refinement or changes are required to answer the research topic of the dissertation perfectly. I applied this step to the themes and generated an initial thematic map. This map shows a relationship between the four major themes. This map is detailed in the result/ discussion chapter. The major constituents of the thematic relationship are: (1) Farmer lockdown Experience; (2) Horticulture, Digital transformation and COVID-19; (3) Low productivity and urgent need of technology adoption; (4) Other themes

Table 2.4 *Steps to Generate Initial Thematic Map*

Codes	Sub-Themes	Main Theme
Labour-intensive activity, border closure, sector struggles to find agricultural labour, interrupt harvesting schedule, health risk, underutilisation of resources	Impact of COVID-19 on agriculture labour supply	Farmer lockdown experience
COVID-19 guidelines, agricultural supply chain, fertilisers, pesticides, agriculture inputs, food supply shortage, food losses perishable goods, shipment delay	COVID-19, agriculture process and supply chain issues and challenges	

2.3.6 Phase 6: Producing the report

The final part of the thematic analysis is writing up the findings (Braun & Clarke, 2006), which involves combining the themes, using data extracts, and generating a long narrative that illustrates the research's consequences and validity.

Limitation:

Data Analysis: The reliability of thematic analysis to produce accurate and cohesive themes from research data has been questioned in the literature (Braun & Clarke, 2006). As previously noted, I addressed the issue by following Braun and Clarke's six phases for a thematic analysis. After describing the research method, In Chapter 3 I do the literature review on the COVID-19 and information technology recent studies are reported.

Chapter 3 : Literature Review

3.1 Introduction

After introducing the purpose of this study in Chapter one, Chapter three aims to review the existing literature as it relates to the research topic: '**Identification of the scope of information technology intervention in horticulture in the Post COVID world – A Thematic Analysis Approach**'. The relationship between information technology and its role in agriculture has been extensively explored in information systems research (or The relationship between information technology and the agriculture industry extensively explore in the information system's research field.). This research will contribute to the literature on the information technology response to the COVID-19 disruption. This chapter begins with an account of selected literature reviews.

3.2 Background

In information systems, extensive research has been conducted on the role of information technology in agriculture. (Banker et al., 2011). The impact of COVID-19 disruption on agriculture has also been widely studied and studies have deliberated on the impact of COVID-19 on agricultural research (Shrestha et al., 2020). For example, one study presents how the pandemic has changed the research discourses about agriculture, and that "resilience" seems to precede "efficiency" in the post COVID world (Bakalis et al., 2020). COVID-19 studies have also suggested that investments in agricultural research "generates higher returns and is a far superior method" for addressing the issues of sustainability (Bank, 2020, p. 12). Scholars have also emphasised on the urgent need for significant and meaningful synthesis of literature and theories in agriculture Digitisation, applied policies and agriculture research (Pannell & Claassen, 2020). Information technology broadly adopted in the agriculture sector, but the research on the impact of COVID-19 on horticulture and the role of Information Technology in its mitigation is currently under assessment across the globe (Bochtis et al., 2020). This research addresses this gap with focus on the COVID-19 situation.

In the sections below, I present the major themes that I found from the systematic literature review.

3.3 Thematic Group

3.3.1 Theme: Impact of COVID-19 on agriculture labour supply

Agriculture, and in particular, horticulture, is a labour-intensive activity. During COVID-19, the horticulture sector saw a shortage of both skilled and semi-skilled labour. Border restrictions imposed during the COVID-19 lockdown was the primary reason for this shortage (Snow et al., 2021). Most of the developed countries are highly dependent upon migrant agricultural labour. In recent years of low unemployment in these countries, the agriculture sector struggles to find domestic farm employees for horticulture, greenhouses, and nurseries. For instance, New Zealand horticulture sector highly depends upon the 15,000 Regional skill employee those come in New Zealand from Pacific countries such as Vanuatu, Samoa, Tonga, and Fiji etc. (New Zealand Immigration, 2021).

The crisis of the shortage of these seasonal employees deepens because of border closure decisions by various governments to control the spread of COVID-19. Many workers have been unable to cross borders, while others have been affected by the virus and commitment of the family care during this period (Bochtis et al., 2020, p. 2). Ramakumar (2020) indicate that this kind of government decision of lockdown and stay-at-home hugely interrupt the harvesting schedule. Due to that, the overall production and supply of perishable goods reduce in the market during lockdown restrictions. Governments worldwide acted fast to exempt agriculture as a necessary service to meet demand and ensure the proper operation of the agriculture production process (Larue, 2020, p. 232). However, labour migration remains a serious concern due to border controls and lockdown in many places. COVID-19 put travel and mobility limitations on foreign workers, who are critical to producing a wide range of farm products, including fruits and vegetables. The agriculture sector struggles to work at its total capacity during the COVID-19.

Agriculture workers who were already working in the sector could not perform regular duties due to COVID-19 guidelines and restrictions at the workplace. The cost of production increased due to establishing new working conditions to keep employees healthy and dealing with sick employees. Therefore, the businesses, government and other institutions working together to develop an effective policy response to tackle these challenges.

Before COVID-19, the agriculture industry was already suffering significant environmental challenges and crop disease, but COVID's limitation on the migration of agricultural labour exacerbated this problem. These problems push farmers to alter their farm management systems. Food security has been harmed in the wake of the mobility restrictions established in

response to COVID-19 measures (Shupler et al., 2021, p. 2). Most of the developing countries in the African continent are vulnerable to mobility restrictions due to their reliance on food imports, high poverty rates, delayed crops, and reduced labour (Priyadarshini & Abhilash, 2021).

As a result of the labour crisis, farm production declined, and agriculture imports became increasingly risky. Countries that rely heavily on food imports, such as those in the Pacific island, Latin America, and Africa, are particularly vulnerable during the COVID pandemic (Zhang et al., 2021).

As a result of the lockdown and border closure, labour shortage in the agriculture sector during planting, food processing, and packaging food prices have risen in many parts of the world in pandemic (Kumar et al., 2021). On the other hand, several nations' trade protectionism policies adversely impact the food supply chain distribution process of agriculture produce, leading to food availability mainly in the agriculture imports countries (Agyei et al., 2021; Mahajan & Tomar, 2021; Okolie-Osemene, 2021).

3.3.2 Theme: COVID-19, agriculture processes and supply chain issues and Challenges

Food, along with energy, is a basic human need. Food (or energy) supply disruptions are significantly more catastrophic than manufacturing supply chain failures (Kumar et al., 2021). For example, consumers may still rationalize their inability to order a dishwasher during the COVID-19 lockdown. However, they may find no justification for the disruption in containing food (or energy) sources (Chenarides et al., 2021a). COVID-19 guidelines impacted the agricultural supply chain because rules requiring the workplace to operate with a limited number of employees were implemented. Such operational issues began the disruption of the agriculture supply chain process (Richards & Rickard, 2020).

In the horticulture sector, there are so many faces in between the farmers and the end-users. These are in form activities such as harvesting, picking-packaging, inventory storage and transportation, retail, and distribution. These activities show the complexity of the supply chain, and this complexity has worsened during the COVID-19 lockdowns (Zhang et al., 2021). The lockdown impacted the supply of agricultural inputs. Farmers, agricultural input sellers, agricultural equipment and spare parts suppliers, and seed, pesticide, and fertiliser suppliers were all affected. China is the one of the biggest producers and exporters of the fertilizer in the world. The trade ban and disrupted supply chain processes imposed both domestically and internationally led to harvesting delays, reduced production capacity, food supply shortage,

and food losses of perishable goods such as fruit and vegetables (Shrestha et al., 2020). In numerous countries, there have been delays in transferring agricultural goods from interior sources to export points. Due to a 14-day quarantine on inbound ships in China, ship unloading is delayed. This has resulted in a container shortage in North America and Europe, significantly limiting exports and imports resulted in supply-side shocks to the food supply chain (Renshaw, 2021).

Apart from the lack of input resources, during the COVID-19 epidemic, short-term food demand was greatly impacted. Due to the closure of food services such as restaurants and hotels during the lockdown shifts consumer demand away from food services to food retail (Larue, 2020). Consumers in many countries resorted to panic purchasing or stockpiling, which increased supermarket sales volume. In OECD countries, consumers spent approximately 30-50% of their food dollars on eating away from home prior to COVID-19. The lockdown closure of bars, restaurants etc. compelled a reallocation of food spending to the food retail sector (Richards & Rickard, 2020). This change impacts the distribution channel of agricultural produce. The overall consumption remains the same, but the supply chain has shifted from food service to food retail, disrupting the sector's supply chain distribution (Li et al., 2020).

According to Chenarides et al. (2021a), the lockdown in March and April 2020 caused a demand shock in the foodservice industry. People began to cook at home, resulting in a shift in sales from foodservice to food retail. This pattern put the perishable foods supply chain to the test for its resilience to handle unprecedented time. The supply chains for fruits and vegetables are substantially more fragmented than those for other agricultural products.

3.3.3 Theme: COVID-19 and adoption of agricultural information technology

Some positive effects were also recorded during that time of COVID-19, such as farmers' growing confidence and resilience in their digital literacy. Exploring new online platforms for virtual meetings for internal and or external stakeholder communications became an immediate trend. Time and effort were spent on redesigning own company websites to cater to a targeted audience; thus, positive gestures for future growth in agriculture. Current studies indicate that information technology can improve communication, automation and decision making (Di Vaio et al., 2020). Shrestha et al. (2020) state that online sales of fertilizer and pesticides will generate digital transactions and data, which will be helpful in the future to share information among the different organisations.

Information technology contributes an immense significance towards tackling significant challenges of the Covid-19 pandemic in the agriculture sector. Changes to the cultivation, processing, transportation and storage processes of horticulture products emerged in response. New emerging technology such as sensing, Digitisation, and automation during Industry 4.0 leads to change the productivities, efficiency, and transparency on the one hand and minimize inventories on the other hand with changing the "on-demand" by adopting the emerging Information System. The Entire agriculture sector observes and revisits its information system and technology to tackle this pandemic and make its business model more resilient and efficient for future needs of the industry.

Moreover, horticultural farmers and the agriculture sector realise the importance of automation, remote operating equipment, and IT connectivity (such as internet broadband) in the day-to-day agriculture process and operation (Kim et al., 2020, p. 13). World Bank also stated that the expansion of digital technology during this pandemic time applied pressure on the horticulture sector to adopt digital technological changes to meet market demand and provide food security to people (Bank, 2020). During the pandemic disruption, the sector needed to rethink and redesign its business model for its clientele whilst meeting production targets (Di Vaio et al., 2020). There is clear evidence that digital readiness positively affects organisation performance. However, not all horticulture farms are ready to adopt these changes (Shrestha et al., 2020). The unskilled and semi-skilled employees are falling behind as compared to the top and middle management. The human nature of change, rapid transformations and digital adaptations bring about scepticism and employee readiness. This is a current concern for the Regional Skill Employee (RSE) who deals with meeting agricultural worker sector from the Pacific nation employees to meet the production target (Adrian et al., 2005).

Urbanization and globalisation in the modern society change the food pattern and food supply chain process. This food pattern and supply chain process was shaken by the Covid-19 disruption (Bakalis et al., 2020). Consumer confidence slumps and income are devastated by the pandemic's presence in New Zealand and throughout, thus adversely affecting retail sales of agricultural products and exports of agricultural goods.

Agricultural policy in the COVID-19 period aimed to encourage farmers to improve their farm management by implementing new technology. Agriculture policy maker and researchers aim

to make the farm management model more resilient for handling this kind of health crisis while also increasing the efficiency and productivity of the agriculture industry (Pannell & Claassen, 2020).

Digital technology is rapidly being used to diagnose and address agricultural production problems, provide recommendations, support agronomic practices, deliver price and weather information, and use digital tools to facilitate marketing, is a clear and developing trend worldwide. The COVID-19 outbreak has paved the way for advanced agricultural information technology adoption for large scale indoor production integrated with the production system. The adoption of new technology also improves the quality of the product. Through technology farmer will use inputs such as pesticides, fertilisers, water and soil more efficiently as well as maintaining improved quality checks during the whole production process. Sensors, robotics, and drones can give farmers with precise information and assist them in increasing production in a climate-friendly manner. Furthermore, improving efficiency and productivity is the ultimate aim of using information technology in farm management systems (Kumar et al., 2021).

In the COVID-19 crisis, product quality, employee health and safety, and meeting the customer demand are the agricultural sector's concerns (i.e., farmers, packhouse owner, food processing companies, and even grocery retailers). Information technology can intervene by various ways to tackle these challenges in the agriculture sector. Further, with a sudden increase in online-channel demand, and a decrease in physical outlet demand, online channels should integrate their data with physical inventory data. The store-level inventories should be visible in online databases. The use of digital technologies could provide a better quality of decision making when faced with severe crises and disruptions in the supply chain (Ivanov and Dolgui, 2020)

3.3.4 Theme: “Food Security” and COVID-19

Food security is undeniably a severe challenge for the world today and will continue to be so in the future. As a result of the COVID-19 pandemic's economic disruption, unemployment increased all around the world. People's incomes have been disturbed due to this pandemic global food security; the primary threat arises because of all of this economic uncertainty. In addition, most countries lack current household surveys on food insecurity, resulting in a lack of global poverty statistics (Swinnen & Vos, 2021).

Devereux et al. (2020) explain that food security has been impacted by COVID-19 outbreaks which consequently caused a disruption to food systems and limited physical access to food. Most of the local farmer’s markets closed during the strict lockdown domestically and internationally. Farmers were trying to organize the local market by strictly following the rules of social gathering and minimal interaction. Small farmers struggled to sell their products directly to the customers as they highly depend on the local market channel. Due to the complex supply chain process in agriculture and COVID-19, lockdowns highlight the importance of farm food sales to tackle “food security” during this challenging time (Middendorf et al., 2021; Yousefian et al., 2021).

Reduced agricultural production (due to disrupted supply chains of agricultural inputs and labour shortages), a decline in household income due to economic downturn, and other factors contribute to high levels of food insecurity. Food security is a more significant concern in developing countries than in developed countries during COVID-19 because developed countries have more economic strength and are less reliant on external resources. COVID-19 severely impacts agriculture, mainly fruit and vegetables, because of significant disruptions in production, transportation, and market performance (Middendorf et al., 2021).

Most farmers are concerned that a lack of inputs, plants, and labour for the sector will result in low production and that the most pressing fear for most farmers is that they will not have enough food to meet the daily needs of customers and leads to a shrink in their income (Swinnen & Vos, 2021).

Major international institutes, farmers, government and corporate businesses realized in the COVID-19 crisis that agriculture and food systems need to be sustainable. The researchers are

discussing one way of achieving this goal through technology development (Leitheiser & Horlings, 2021).

3.3.5 Theme: IT in agriculture marketing in COVID-19 world

The term Agricultural marketing is used by Akhmadi and Pratolo (2021) to refers to the combination of all procedures involved in the transmission of agricultural goods from farmers to the final customer. The meaning of this term has been extended to set the market price based on the commodity quality, improve supply chain efficiency, opportunities for value chain expansion, improve communication and reduce the transaction cost. In other words, online marketing is the process of using information technology during the farm market. In particular, operations from farm to final customers through various phases such as marketing, online transaction, communication, and delivery provide value to customers, sellers, and the agricultural sector (Goswami & Jatana, 2021).

Agriculture products demand increased during COVID-19, but the strict lockdown imposed by the various governments around the world forced farmers to harvest and market their crops in the disrupted supply chain. Supply chain disrupted due to transportation barriers, market closure or limited hours of operation and labour shortage in the agriculture farm and the market operation (Mahajan & Tomar, 2021, p. 37). During COVID-19, health risks and insecurity of catching virus during physical visits motivate consumers to use the online purchasing process. Consumer behaviour during COVID-19 is described by the theory of perceived risk, which claims that the consumer's risk perception substantially impacts their buying behaviour (Naeem, 2020).

The new way of purchasing various products such as food and household essentials through online platforms has a significant impact on agricultural marketing trends, particularly during the COVID-19 (Ben Hassen et al., 2020). In recent years, internet usage increased rapidly for economic purposes such as product search, information, and commerce (Li et al., 2020, p. 577). This may also be observed in the widespread use of technology in business and economic activities, expansion of telecommunication infrastructure and affordability of technological devices. These are the factors that lead to online purchase trends during COVID-19 (Akhmadi & Pratolo, 2021).

There are numerous online platforms for sellers and buyers, including social media (online shopping), websites, and marketplaces. Anshari et al. (2019) explain that a marketplace is a

virtual location that allows vendors and buyers to conduct deals or trades. Information technology can play a significant role in shaping and influencing this new era of online shopping trends in the future for productivity and sustainability of the agriculture sector and addressing crises such as the current health crisis (Stephens et al., 2020).

These marketplaces were created to help farmers gain economic empowerment, and they appear to be helpful in the agriculture sector post COVID recovery (Akhmadi & Pratolo, 2021; Thilmany et al., 2020). In recent years, agriculture marketing has transitioned to online or digital marketing. The Indian government launched a virtual network market in 2016 to establish the Electronic National Agriculture Market (eNAM) portal (Goswami & Jatana, 2021). eNAM is an online platform that allows farmers to sell their products online while maintaining social distance during the COVID-19 health crisis. It indicates that the platform will help keep the supply chain process as smooth as possible and mitigate the spread of the virus.

The adoption of agriculture marketing is also used to increase the sector's market shares and, income and profit improvement of the industry (Akhmadi & Pratolo, 2021). Due to the COVID-19 outbreak, the present model of sales and purchase has been forced to change. As a result of information technology, consumer lifestyles have changed substantially in the COVID-19, and online purchase has grown by many folds (Ben Hassen et al., 2020, p. 5). Antonella et al. (2021) state that the Covid-19 outbreak exacerbated this tendency, with 30% of consumers worldwide claiming to have begun utilizing e-commerce during the shutdown.

The online grocery shopping trend in COVID -19 was bolstered by customers placing more orders for pickup and delivered online (Li et al., 2020). This form of communication indicates demand forecasts to the grocery stores and sellers, which leads to cheaper inventory costs. On the other hand, online shopping is also convenient, time saving and safe during COVID-19. One survey across 20 states in the US indicates that in 2020 online grocery marketing was worth 10% of the $1.04 trillion grocery market and is predicted to approach 20% by 2025 (Redman, 2020).

Various NGO’s and Government agencies creating platforms in the form of mobile applications and other online platforms assist farmers and consumers in meeting supply and demand during the current pandemic (Saha & Bhattacharya, 2020). Due to the COVID-19 outbreak, the present model of sales and purchase has been forced to change. As a result of

information technology, consumer lifestyles have changed substantially during COVID-19, and online purchase has grown by many folds (Thilmany et al., 2020). Antonella et al. (2021) state the Covid-19 outbreak exacerbated this tendency, with 30% of consumers worldwide claiming to have begun utilizing e-commerce during the shutdown. During the lockdown, the number of food-buying applications increased dramatically (Bhatt, 2020; Kappan, 2020; Nainar, 2020; Special Correspondent, 2020b).

By encouraging customers to switch to online retail systems, supermarkets improve their purchasing predictions. Necessary purchases are evenly balanced, based on recorded demand in the online retail system and, better communication with delivery partners to enable more workable logistics.

During the time of COVID-19, various research found that the local and regional food producers and operators also used e-commerce. In 2015, just 8% of farmers who directly sell their agricultural produce to customers used online marketplace platforms (O'Hara et al., 2021). The challenges of COVID-19 lockdown restriction, social distancing and other guidelines to combat the virus compels a business to adapt their marketing and sales activities on the internet. During the epidemic, the popularity of internet food purchases and online transactions increased. The E-commerce sites traffic also climbed dramatically. Although traffic does not necessarily translate into sales, it indicates a growing interest in online local food options (since more visible platforms of mainstream food retailers are easier for the customer to find and use). During COVID-19 in May 2020, the web-based marketplace database (Market Maker) that connects producers and consumers had a 100 per cent increase in profile views compared to the same period the previous year. (Akhmadi & Pratolo, 2021).

3.3.6 Other Themes

Theme: Resiliency of supply chain

One important theme that has been widely discussed in the literature is the resiliency of the agricultural supply chain. During this pandemic, a fundamental concern arises about how resilient the food supply and food system is and how (or should) it be made more resilient? The term "resilience" is difficult to define; in the business world and the supply chain context, even supply chain professionals have trouble defining exactly what it takes to robust supply chains. Tendall et al. (2015) described the food system resilience as providing sufficient, acceptable and accessible food to everyone in the face of various and even unforeseen disturbances. Ponomarov and Holcomb (2009) suggest that supply chain resilience can be defined by robustness, flexibility, sustainability, recovery, and readjustment.

Furthermore, Chenarides et al. (2021a) support a resilient supply chain as flexible enough for shippers to migrate from one distribution channel to another without losing continuity or output. COVID-19 restriction has forced the horticulture and information technology sector to think about the most interesting question: where the agriculture sector goes from here? This lockdown period indicates that the sector needs to be more resilient by adopting digital technology in AI, cloud computing , IoT, sensors, automation, roots, etc. (Di Vaio et al., 2020, p. 3).

Fruit and vegetable demand increased in the COVID-19 period; however, due to disruptions in the agri-food supply chain, agriculture and retail sectors could not meet that amount of food. Farm production had to continue due to the biological nature of the process, while packaging, storing and distribution processors required time to respond to the new demand scenario during COVID-19. Horticulture items were wasted until the system was adjusted.

IT may play an important role in improving fruit and vegetable storage in crucial times like current health crises. Improving the storage facilities during this pandemic is very important to tackle food insecurity and meet the healthy food demand.

Theme: Impact of COVID-19 on consumer behaviour

Consumer interaction and engagement has significantly changed during the social distancing norms in the COVID-19 lockdown. These new normal norms during the COVID-19 restriction change the consumer buying behaviour and demand for food, affecting the horticulture products demands and sales (Bakalis et al., 2020b, p. 168). In this case, online shopping through information technology devices rapidly increased by many folds (Bakalis et al., 2020b, p. 171). The concept of the homebody economy emerged during this time of the pandemic, i.e., people working, studying from home, online entertainment. These sorts of new lifestyles change the eating pattern of the people as well.

At the beginning of this pandemic, especially in April-May, the period of full lockdown, the amount of time spent searching the food and cooking website spike about 71%. Home cooking and homemaking have become big things among people around the world. It hugely impacts rich produce, especially fruit and Vegetable's demand and consumption in these months of the lockdown because the wellbeing of the others may be included in the household utility function. Consumer preference for fruit and vegies increased and still increasing, which shows the pressure on the producers to achieve these goals of high yield and high-quality products in the market.

Online shopping skyrocket during that time and the producer and business challenges meet that demand. The real-time digital information system in the horticulture sector improves the organisation's decision-making process, which will directly contribute to cost reduction and increased profit.

The closure of food services such as restaurants and hotels during COVID-19 lockdown shifts consumer demand from food services to food retail. This change impacts the distribution channel of agricultural produce. The overall consumption remains the same, but the supply chain has shifted from food services to food retail, disrupting the sector's supply chain distribution.

After reviewing existing literature on how COVID-19 affects the horticulture sector and the role of information technology in the sector, in chapter four, I elaborate on the thematic relationship of various themes and sub-themes

Chapter 4 : Findings

4.1 Introduction

This chapter discusses the thematic analysis findings regarding the various issues and challenges that horticulture faces during the COVID-19 pandemic and the role of information technology in addressing these challenges. Thematic analysis of the literature on Information technology, horticulture and COVID-19 produced four main themes. Each main theme has sub-themes that present the key findings. The figure below provides a thematic map of these themes.

Table 4.1 *Final Thematic Map of Main Themes*

Themes	Sub-Themes
Farmer lockdown experience	Impact of COVID-19 on agriculture labour supply
	COVID-19, agriculture process and supply chain issues and challenges
Horticulture, Digital transformation and COVID-19	COVID-19 and adoption of agricultural information technology
	Impact of digitisation on horticulture product quality
Low Productivity and urgent need of technology adoption	Information technology in agriculture marketing in post COVID world
	Food security and COVID-19
Other themes	Impact of COVID-19 on consumer behaviour

In this chapter, I present these themes and sub-themes support by the content from the peer-reviewed research articles. The aim is to use these themes and sub-themes to find the answer to the main research questions. The main themes identified are:

(1) Farmer lockdown experience;
(2) Horticulture, Digital transformation and COVID-19;
(3) Low productivity and urgent need of technology adoption;
(4) Other themes.

Table 4.2 *Primary Codes, Sub-Themes and Main Themes*

Codes	Sub-Themes	Themes
Labour-intensive activity, border closure, sector struggles to find agricultural labour, interrupt harvesting schedule, health risk, underutilization of resources	Impact of COVID-19 on agriculture labour supply	Farmer lockdown experience
COVID-19 guidelines, agricultural supply chain, fertilizer, pesticides, agriculture inputs, food supply shortage, food losses perishable goods, shipment delay	COVID-19, agriculture process and supply chain issues and challenges	
Virtual meeting in COVID-19, digital transaction, digitisation, automation, remotely operating equipment's	COVID-19 and adoption of agricultural information technology	Horticulture, Digital transformation and COVID-19
Productivity and efficiency, products quality, new farm management, better use of inputs, quality check,	Impact of Digitisation on horticulture product quality	
Farmer to end customer, Information technology in market operation, health risk, food buying application increased	Information technology in agriculture marketing in post COVID world	Low productivity and urgent need of technology adoption
Economic disruption, unemployment, and income loss disrupted the food system, social distancing, struggling local farmer's market	Food security and COVID-19	
Virus, limited operation, temporarily closure of agriculture operation, food supply delay, shortage of healthy food, online purchase, a new trend	Impact of COVID-19 on consumer behaviour	Other themes

4.2 Farmer lockdown experience

As noted in the academic literature, the farm sector face a number of challenges during the COVID-19 (Devereux et al., 2020, p. 770). The border closure and lockdown decision by countries around the world adversely impact the agriculture sector in terms of labour shortage, and various agriculture inputs supply was disrupted. This first theme that emerged from the literature review in this research has sub-themes: (a) Impact of COVID-19 on agriculture labour supply; (b) COVID-19, agriculture process and supply chain issues and challenges. In the next part of this chapter, I will explain these sub-themes of the four main themes of this research.

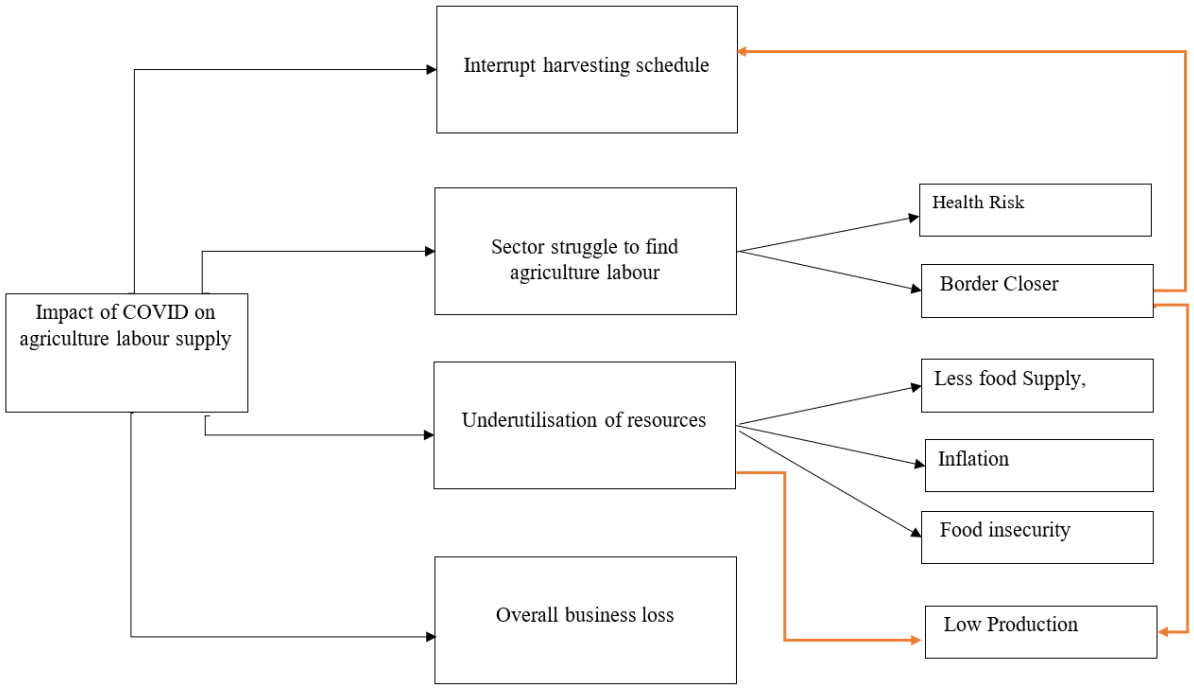
4.2.1 Impact of COVID-19 on agriculture labour supply

As currently, the world is living in the global age, an unforeseen outbreak of COVID-19 would have negatively impacted the global agriculture sector, affecting every stakeholder involved in the industry. Agriculture work was already labour-intensive and challenging, with extended and socially inconvenient working hours before the COVID-19. As a result, agriculture workers were already under stress, and the industry had a high staff turnover rate (Wiltshire, 2018). There is a massive demand for skilled and semi-skilled labour in the agriculture sector. The border closures and lockdown decision by most of the countries caused significant challenges in front of the agriculture sector as:

1. Interrupted harvesting schedule
2. Sector struggle to find agricultural labour
3. Underutilization of resources
4. Overall business loss of the sector

During the pandemic, the industry is experiencing a labour shortage for various reasons, including the government's decision to close borders and implement lockdown measures to control the spread. As a result, harvesting schedules are thrown off, and agricultural productivity suffers. Two instances of adverse outcomes are food inflation and food insecurity. Figure 4.1 below presents the relationship between these challenges.

Figure 4.1 *Impact of COVID-19 on Agriculture Labour Supply*



COVID-19 has had an enormous impact on agricultural business operations all around the world. Under these unprecedented circumstances, the sector was facing a massive shortage of migrant and local agricultural labour. Agriculture is a time-sensitive industry. During the pandemic, the sector's harvesting routine was disrupted. As a result, overall production and efficiency in the sector suffered (Thilmany et al., 2020, p. 90).

COVID-19 restriction of social distancing and other health and safety measures such as wearing masks, sanitising and washing hands regularly under new normal adversely affect the sector by increasing the cost of labour (Ben Hassen et al., 2020; Larue, 2020). Under COVID-19 guidelines of social distancing on the workplace, only one-third of the total agriculture workforce could return to work at a time. The unexpected result of these recommendations was that the sector underutilised resources during the COVID-19. The agriculture farm was not running at its total capacity during the pandemic. The overall production of the sector decline. Therefore, there is less food in the market to meet customer demand.

The epidemic harmed every stakeholder involved in the agriculture industry, whether directly or indirectly. During the pandemic, due to the less production of agricultural produce, there was food inflation. Consumers are left in a state of food insecurity as a result of this.

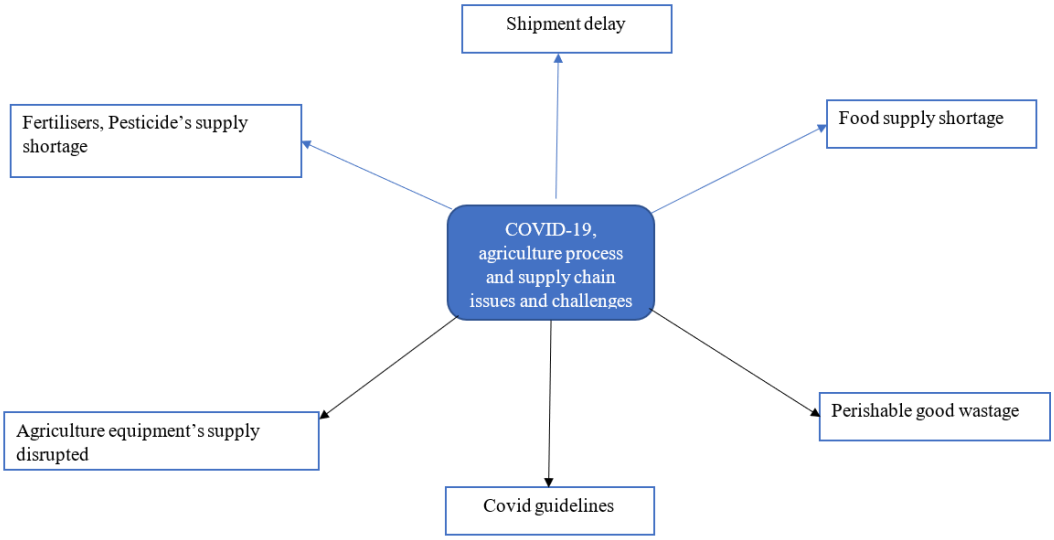
4.2.2 COVID-19, agriculture process and supply chain issues and challenges

It has been found in the literature through various research articles that the supply chain of agricultural inputs and supply of agricultural finish products has been disrupted during the COVID-19 pandemic lockdown period. Due to the supply chain disruption farmers and horticulture business owner faces various challenges that we find as codes in our research sub-theme as:

1. Agriculture equipment's supplies disrupted;
2. Shipment delay;
3. Fertilisers, pesticides, seeds supply shortage;
4. Food supply shortage;
5. Perishable good wastage, i.e., fruits and vegetables;
6. COVID-19 guidelines

Figure 4.2 below describes the relationship between the supply chain sub-themes and the main theme.

Figure 4.2 *COVID-19, Agriculture Process & Supply Chain Issues and Challenges*



The codes of this sub-theme are discussed below:

Agriculture equipment's supplies disrupted

According to the government's COVID-19 health and safety guidelines to the agriculture sector, workers must use their own equipment and agricultural machines to stop the virus from spreading. Border closures and lockdowns had an impact on the agricultural equipment's supply. According to numerous studies, at the beginning of the lockdown period, the supply of agricultural products is highly disrupted in most countries.

Food supply shortage:

During March-May 2020, the strict lockdown and closure of most public transportation and public schools, grocery store retails and foodservices hotels, restaurants and bars, etc., could adversely impact the agriculture food transport and supply. This disruption creates the fear of food insecurity among people.

Fertilisers, pesticides, seeds supply shortage

In the long run, the impact of COVID-19 is also seen on the input supply chain interruption in the agriculture sector. Therefore, the sector was facing a shortage of farm plants, seeds,

pesticides and fertilisers during that time period. Bochtis et al. (2020) indicate that these types of agriculture input supply chain shocks have had a harmful impact on agricultural produce production

Perishable goods wastage i.e., fruits and vegetables:

After a year, the researchers discovers that the supply chain for perishable items such as fruit and vegetables is highly disrupted, and the sector is not resilient enough. The sector is interrupted to the extent that the supply of fruit and vegetable does not meet customer demand (Chenarides et al., 2021b). The producer and exporter take time to readjust the retail market for food production, shipment and export of the fruit and vegetable to restore export returns to pre COVID levels.

COVID-19 guidelines:

Uncertainty arises among people from the COVID-19 guidelines and restrictions for operating grocery stores with social distancing, wear a mask on premises, a limited number of people in the grocery store. During the COVID-19 crisis, the government imposed reopening regulations such as social distancing, hygiene requirements, and other health and safety requirements. Therefore, agriculture work has become more demanding in COVID-19 (Swinnen & Vos, 2021). Overall, the impact of the COVID-19 epidemic has caused tremendous damage to the global agriculture sector, and information technology will be critical in helping the sector achieve pre COVID level normal agriculture operation process.

Shipment delay:

Under the COVID-19 restriction, the health and safety check of the shipment delivery increased leads to delay on the port. This trend leads to a shortage of containers. These challenges adversely affect the overall supply chain process. On the other hand, Devereux et al. (2020) explain that to accommodate the local demand for food, the majority of governments decided to suspend foreign trade at the start of the epidemic. Because of these national and international trade restrictions, food security was threatened. Food distribution becomes unequal as a result of directing food logistics towards meeting local demand.

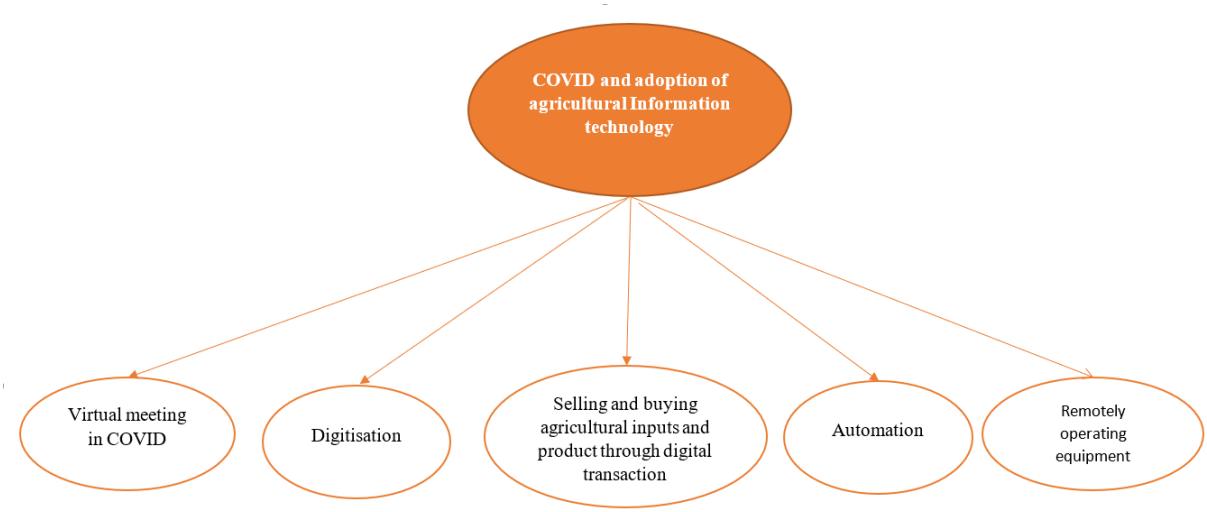
4.3 Horticulture, Digital transformation and COVID-19

The use of information technology in the horticulture sector during the COVID-19 had emerged sub-theme in our research as shown in the below table:

Main Theme	Sub-Themes
Horticulture, Digital transformation and COVID-19	COVID-19 and adoption of agricultural information technology
	Impact of Digitisation on horticulture product quality

4.3.1 COVID-19 and adoption of agricultural information technology

Figure 4.3 *COVID-19 and Adoption of Agricultural Information Technology*



Virtual meeting in COVID-19:

The agriculture sector was using less technology for efficiency and productivity compared to other sectors before COVID-19. However, during the COVID-19 pandemic, social gatherings and movement of people were severely disrupted, and farmers and other agriculture-related government and non-government organisations used technology to hold virtual meetings to share their ideas on how to address the issues generated by the pandemic.

Digitisation

It has been found in the research literature that after COVID-19, the industry experts and researchers are thinking to speed up the technology adoption process in the current business model of the farm management system (Di Vaio et al., 2020). In the long run, business model changes mean more automation and digitisation for production and processing lines. Therefore, this will help to make the sector resilient and efficient to tackle similar challenges in the future (Akhmadi & Pratolo, 2021; Shepherd et al., 2020).

Selling and buying agricultural inputs and products through digital transaction:

The entire world grapples with the problems of the COVID-19 pandemic. Most of the countries witnessed the Digitisation of the agriculture, retail and supply chain. Improvement in the existing information technology infrastructure facilitated through government policies and decisions also indicates the sectors' digitisation (Chavas & Nauges, 2020). Huff et al. (2015) explain that the need for digital innovation in helping the farm sector become more resilient to future threats is also highlighted by this outbreak. Due to COVID-19 restrictions, the input market was highly affected. Farmers were unable to purchase seeds, insecticides, fertilisers, and other farm equipment. According to the various research, during the pandemic, online sales of these agricultural inputs increased. This trend indicates that information technology is being used to buy and sell high-quality agricultural inputs and machinery during COVID-19.

Automation:

Information technology is used to automate processes that are generally repetitive and uniforms, such as quality control and packing, to name a few. (Weersink et al., 2021). During the COVID-19 outbreak, however, social distancing standards and health and safety considerations force the farm management system to automate the agriculture processes as much as possible. The farmer's organisations decided to contain the virus and continue the agriculture production process to meet current demand. During COVID-19, the agriculture sector in most countries struggled to obtain agricultural labourers, particularly in the horticulture sector. Therefore, farmers realised that the long-term solution to this challenge is to invest in labour-saving technologies and automate the agriculture process to make the agriculture industry more resilient to future pandemics.

Remotely operating equipment's:

Farmers use sensors before COVID-19 to make the best use of agriculture inputs in the production process. They employ these sensors and a variety of other modules to collect data on soil quality, the amount of fertilisers and pesticides used in the production process, and any crop disease. This data was collected through Wi-Fi connectivity and stored on a cloud platform for better farm management. This setup seems very helpful during the COVID-19 as the pandemic lockdown stops the regular visit of the farmer to their agriculture farm. Most farmers use this remotely operating equipment to continue the agriculture process (P. Visconti et al., 2020).

4.3.2 Impact of Digitisation on horticulture product quality

In the agricultural sector, it has been discovered that farmers that use information technology have higher production, efficiency, and product quality, which leads to the overall benefit to the sector.

Figure 4.4 shows the sub-theme "Impact of digitisation on horticulture product quality".

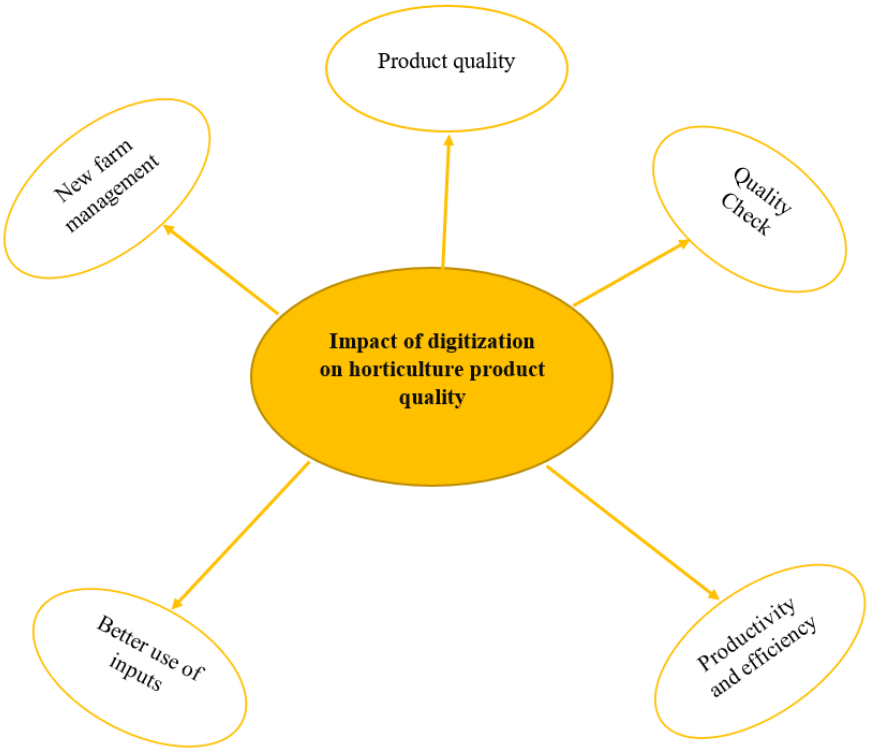
Better used of inputs:

Digital technology is used by farmers in the form of sensors, robotics, and drones. They mostly employ these gadgets to obtain precise data to improve the efficiency and productivity of agricultural inputs while remaining environmentally conscious (Antonella et al., 2021).

Quality Check:

In agriculture, digital technology is also used to check the quality of the product. Agricultural information technology is used to monitor any disease and pest activity during the harvesting process. This process improves the quality of the final product. As a result, the overall production and product quality of the production increase.

Figure 4.4 *Impact of Digitisation on Horticulture Product Quality*



New farm management:

According to numerous studies, the use of digital technology in agriculture pre COVID-19 was very low. The majority of agriculture firms were less likely to use the internet to receive orders. The vast majority of agricultural businesses do not have an email address or a website. However, the COVID-19 serves as a catalyst for the agricultural sector to think about and change the farm management system. As online buying behaviour increased during the pandemic time. It has been found that the online ordering system and e-marketplace platform set up in the new farm management system was widely used during that time period. By adopting this information technology, the online agriculture product sale increased mainly during the time of COVID-19. Before COVID-19, online grocery sales in Canada accounted for about 1.5 per cent of total sales, but by March 2020, that figure had risen to 9%. This trend indicates that the agriculture produces wholesalers and retail grocery stores used information technology during COVID-19 to deliver farm produce to the end customers.

Product quality:

The online buying of food products during the COVID-19 pandemic gives the customers more bargaining power to compare the various services such as prices, quality, and delivery options from different sellers. On the other hand, farmers now have a database on customers taste, preferences, and price ranges for agricultural products. Farmers are now more pressured to provide quality food products at an affordable price to meet customers' demand. The certainty of supply is increased by selling the product through an x platform. Farmer has more transparency and confidence in their products sale decision-making process. As a result, information technology intervention during the COVID-19 in the agriculture market improves product quality. Buyers can receive a better product than pre-COVID-19, and farmers have more clarity on the customers' product quality demand and price to their agriculture products.

Productivity and efficiency

Previous research has revealed that information technology innovation boosts farm field productivity and efficiency. The demand for food drastically increased during the time of COVID-19. The agriculture sector realises that more agricultural information technology innovation and adoption will be required in the future to combat a similar type of epidemic and meet such a high demand for food. The infrastructure improvement and more use of information technology during the pandemic in the agriculture sector indicate that the sector is

putting more effort to change the traditional way of doing agriculture activities. The sector is putting all these efforts to make agriculture productive and efficient for future shocks.

4.4 Low productivity and urgent need of technology adoption

Under COVID-19, overall productivity decreases, and the need for technology adoption in agriculture returns to the forefront of research. This theme is comprised of two sub-themes, as shown in the table below.

Main Theme	Sub-Themes
Low productivity and urgent need of technology adoption	Information technology in agriculture marketing in post COVID world
	Food security and COVID-19

4.4.1 IT in agriculture marketing in post COVID world

Food buying application increased:

During the COVID-19 lockdown the buying food through online platform was increased by many folds. The food delivery application business plays its part to continue the food services in the COVID-19. These businesses not only fulfil the goal of food security but also the contactless delivery help to control the spread of the virus.

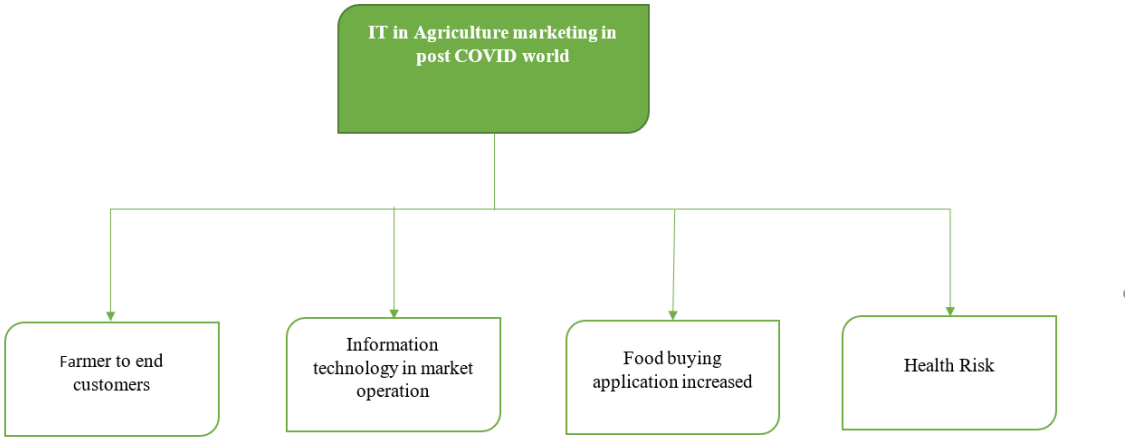
Information technology in market operations

As seen in the literature during the lockdown, the online shopping trend increased because of social distancing, health and safety, and other guidelines to control the spread of the virus. According to the online marketplace (Bedukmutu) in Indonesia, the total number of trades products increased by around five times from 3,124 to 15,019 in 2019 to 2020.

Farmer to end customers:

The model can tackle the current health crisis and be ready for the future to tackle these kinds of shocks. Information technology intervention in farm buying and selling operations has made it easier for customers to buy food at reasonable prices throughout the epidemic. On the other hand, information technology has played an essential role in providing farmers, agriculture business owners, and small businesses with market access during lockdowns

Figure 4.5 *IT in agriculture marketing in post COVID world*



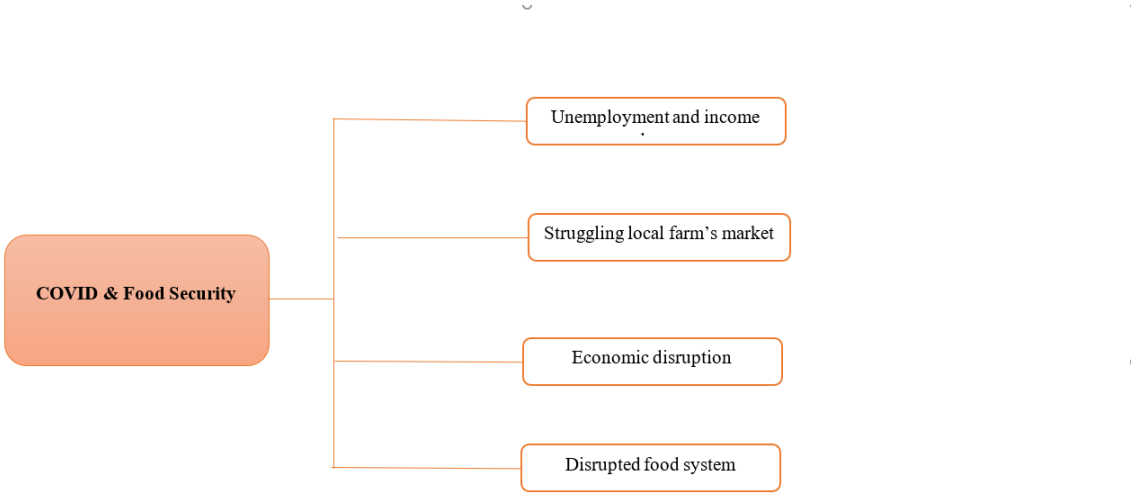
Health risk:

To combat the spread of the virus during COVID-19, all countries around the world used the COVID-19 tracing application. The government can track and monitor people's movements with the help of this application. All businesses were told to use the contract tracing application to track visitors to their premises, such as farms, packing houses, and other processing facilities. It highlights how information technology supports the sector in continuing its business operation during that unprecedented time.

4.4.2 Food security and COVID-19

This sub-theme on Food security and COVID-19 shown by the figure below and discussed the various challenges faced by people to get enough food during COVID-19

Figure 4.6 *COVID-19 and Food Security*



Unemployment and income:

Due to this economic disruption, unemployment rises at the beginning of the pandemic. The pandemic disrupted jobs, income and the overall economy. Most of the household income decrease due to lockdown leads to reduce the purchasing power of people. The majority of the household express the concern that COVID-19 make it more difficult to buy enough food for their family regularly. COVID-19 hit hard the agriculture marketplace where the people purchase their food before COVID-19. Most of those agriculture markets were permanently closed or significantly disrupted during the pandemic. Food inflation occurred due to that economic disruption caused by COVID-19. All of these factors raise the primary concern of food insecurity during the pandemic in the general population.

Struggling local farm's market

To stop the spread of the virus, several governments and municipal entities have imposed lockdowns, which have resulted in the closure of local farm markets. During the pandemic, agriculture farm marketplaces were closed or operating with minimum capacity. Farmers found it very difficult to sell their agricultural produce in the market. During that time, customers were having difficulty obtaining fruit and vegetables and other farm goods. It was also revealed that customers are interested in purchasing goods such as fruits and vegetables directly from farms. However, the main barrier between consumers and farmers was communication and logistics. COVID's struggling food market system leads to food insecurity among the general public. Due to pandemic restrictions, people's food consumption patterns shift throughout this pandemic.

Economic disruption:

In the COVID-19, almost every country has experienced economic shock and has seen negative economic growth. Individuals are experiencing uncertainty and worry of decreased household income as a result of the economic shock. As a result of the economic downturn, people's consumption and purchasing behaviours changed during COVID-19. People's food preferences switch from food service to food retail during COVID-19. One reason was the closure of hotels, restaurants, bars, and other similar establishments during the lockdown. Another explanation was a drop in household income due to the COVID-19 economic disruption. As a result of the uncertain future economy, consumers cut back on their spending during pandemics.

Disrupted food system

COVID-19 has a detrimental influence on horticultural product harvesting, procurement, and processing. According to the literature, the food supply chain for perishable foods was severely harmed during lockdowns, which results in fruit and vegetable waste. The majority of the population's nutritional needs are threatened due to all of these difficulties in the COVID-19.

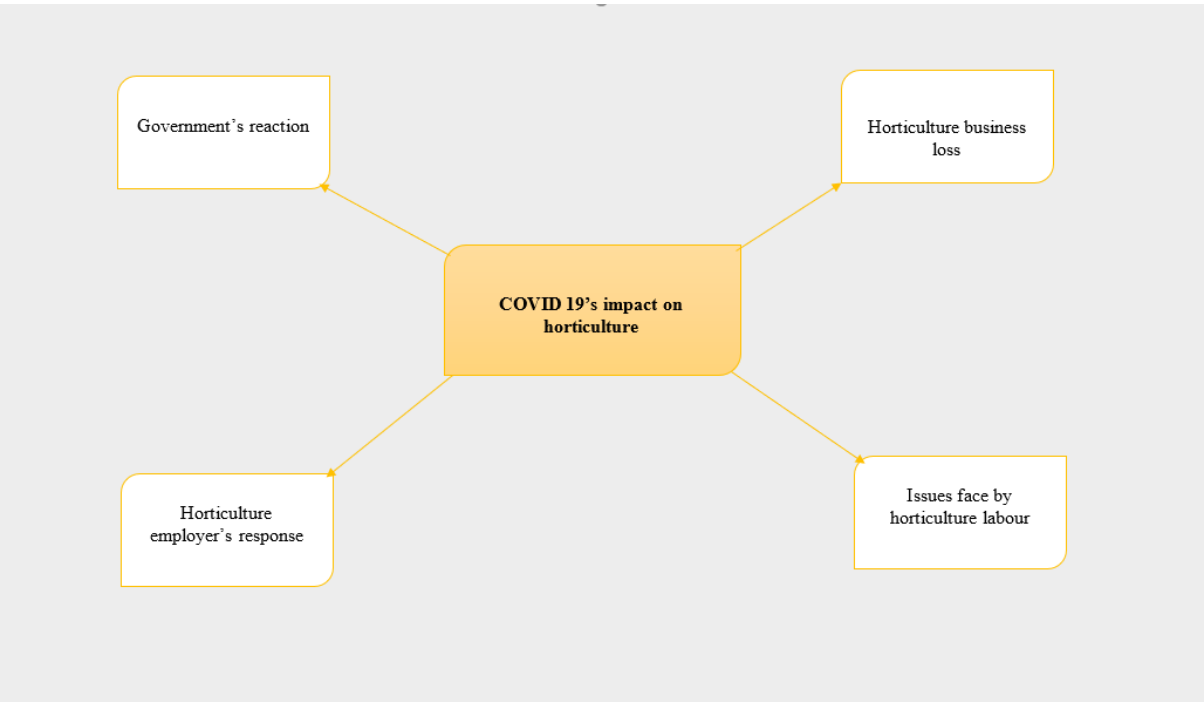
4.5 Other themes

4.5.1 Impact of COVID-19 on consumer behaviour

In the initial phase of this pandemic, consumers completely stop buying the products through grocery stores or other retail channels for a short period. The supply chain infrastructure of the retail sector was vulnerable during that time. To combat the spread of the virus, the government issues COVID-19 guidelines of social distancing, wearing the mask, and other hygienic and health and safety guidelines that lead to the trend of online shopping during the lockdowns.

Economic policies are also significant for the recovery of the agriculture sector.

Figure 4.7 *COVID-19's Impact on Horticulture*



Governments' response:

According to research, during the epidemic, 25% of agricultural firms in developed countries like Canada did not have enough finance to meet short-term financial obligations. It suggests that the farmers required immediate financial assistance from the government to meet the demand at this unprecedented time. Even with government support, many countries expected that the sector's overall growth would decline in 2020. Government assistance was also provided to strengthen the information technology infrastructure, such as increasing the

internet speed at no additional cost. The governments made these policies and decisions because the online buying trend increased during the pandemic lockdowns.

Government policies and decisions in trade, marketing, and financial support were also vital for the smooth functioning of the food supply chain. The primary objective of these policies and decisions was to ensure that the public had enough food during a pandemic. The majority of the government assured the population that food, medical care, and other necessities would continue to be available even if the country were under complete lockdown. To meet the demand for these requirements, the government recognizes that it must diversify its global trade and increase domestic food production.

Various governments also address the issue of food shortages and malnutrition during pandemic lockdowns by giving food subsidies. It emphasizes the relevance of the agriculture industry during pandemics. The government believes that the sector must become more digitally inventive, productive, and efficient and resilient enough to tackle this kind of pandemic in the future.

Most developed countries have simplified the visa process for agricultural workers to handle labour shortages in the agriculture sector during the pandemic. Some of the countries give the border exemption to the agriculture labour to enter the country. This decision was to continue the agriculture production process.

Effects of COVID-19 on horticulture business:

While on the other hand, the developing countries were not that resilient to tackle the COVID-19 supply chain disruption because of a lack of technology, infrastructure and other resources. The other challenges have emerged in these nations, such as malnutrition and hunger, especially children. The government of developing countries ensures that the local supply of fruit, vegetables, and other agriculture products runs smoothly to access these products easily.

Siddiquei and Khan (2020) explain that the COVID-19 outbreak in the United States, Brazil, United Kingdom, France, Italy, and other nations has adversely affected agricultural exports from developing countries such as India, Pakistan, and Indonesia. According to researchers, India's agricultural exports, such as vegetables, have decreased by 20-40 per cent

Horticulture employers' responses:

During the epidemic, the majority of employers struggled to recruit enough staff to keep their operations running. On the other hand, the farm business could not run at total capacity due to COVID-19 guidelines regarding health and safety and social distancing. All of these factors increased the cost of producing agricultural products. Researchers also assume that the business model changes in the agriculture sector to tackle these challenges may change the agriculture sector forever (Richards & Rickard, 2020).

Agricultural markets closed as a result of the strict shutdown. Farmers endured difficulty in selling their agricultural products. The price of fruits and vegetables dropped radically. In India, for example, the cost of tomatoes was two rupees per kilogram; otherwise, the farmers are unable to sell their crop. During the closure, transportation and shipment were also interrupted, and horticulture business owners struggled to transport their products inside the country and beyond.

Workers in the agri-food supply chain are equally susceptible to the virus as the general public, and more so in some cases. Due to the outbreak amongst employees and absenteeism concerns, a few fruit and vegetable producers, food packhouses, and companies were forced to limit operations or temporarily close. The temporary closure of these operations resulted in a delay, which affected the supply chain process of the food retailer.

Issues faced by horticulture labour:

Food insecurity is also a concern among agriculture farm employees due to the disruption in the horticulture sector's production process during the crisis. As a result of the strict lockdown and border closure, farm labourers find it challenging to migrate and keep their jobs. The COVID-19 reduces farm labourers' household incomes, resulting in lower purchasing power. The agriculture sector faced the challenge of making the farm job more productive and earning better before the COVID-19. Due to the lockdowns, labour shortages pressure the sector to shift from labour-intensive to capital intensive. Therefore, most governments and companies are investing in digital innovation, information technology for automation, sensor, robotic and IoT, etc. These changes put agriculture labour into a more vulnerable position during the structural shift of the sector. Most of the farm workers fear that they will lose their job in the future. But on the other hand, the research indicates that information technology does not put agriculture workers into job loss or unemployment. Information technology and digital

innovation will make agriculture production more sustainable and more accessible, and safer for the agriculture workforce.

Chapter 5 : Discussion

This chapter aims to answer the second research question, i.e. :
What are the potential areas of information technology intervention in horticulture in the post COVID world?
To answer the question, I look at themes from previous research presented in the preceding chapters. The themes I discussed previously were labour shortage, consumer buying behaviour, supply chain issues and challenges. In this section, I will focus on possible IT interventions around these themes.
I will discuss the relationship between themes and sub-themes to build a framework for understanding how the current COVID-19 pandemic challenges differ from those faced in the past by the sector. Additionally, how information technology intervenes to tackle these challenges.

5.1 Labour shortage and IT intervention

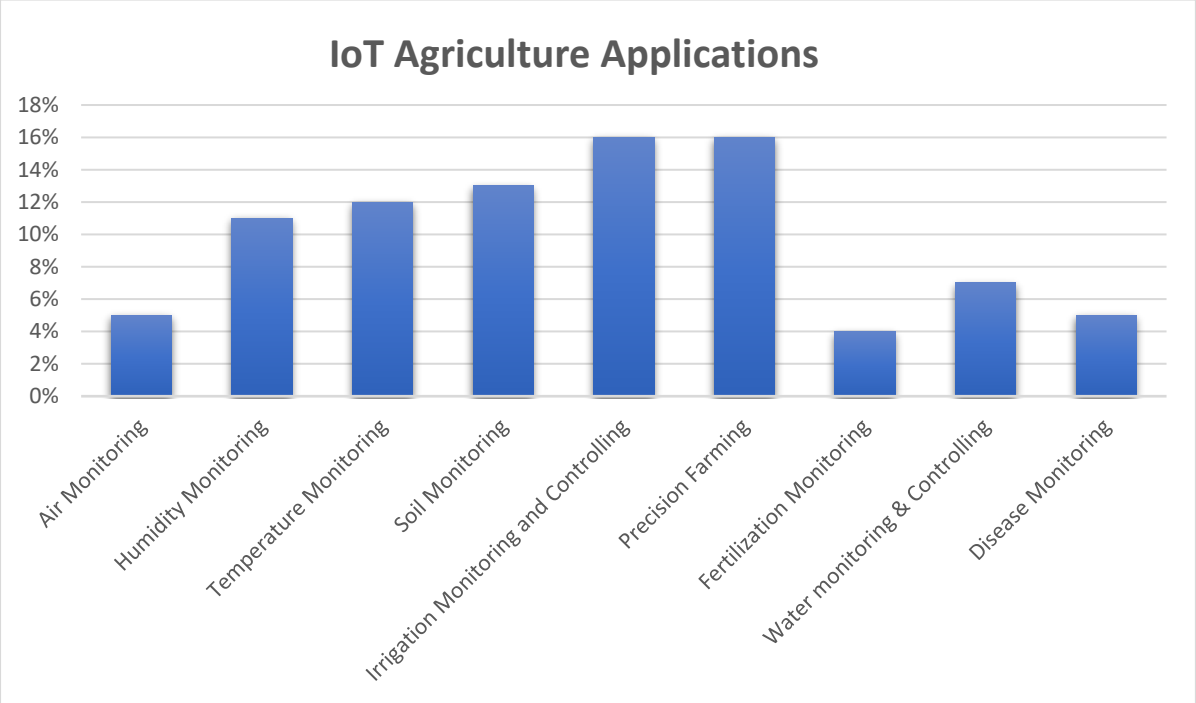
The first theme discussed in the finding chapter is that farmers experience labour shortages in the COVID-19 pandemic. In past studies, it has been found that labour shortage in the agriculture sector was not new to the sector (Guthman, 2017; Phyo et al., 2016; Wiltshire, 2018). Agriculture farm working conditions and pay rate was the reason for the labour shortage in the sector. Agriculture labour's withdrawal from the sector and moved to the cities to find better work conditions and other paid jobs. However, it was never studied how pandemics and the subsequent border closures could impact labour issues in horticulture. In the past, the impact of pandemics such as influenza has been studied. Some studies have discussed border closure as a proof of concept for protecting the island countries from the pandemic repercussions (Boyd et al., 2017). However, there are no studies to the author's knowledge that have discussed the impact of the pandemic, which led to border closure on the horticultural labour supply. COVID-19 worsened the labour shortage because of the border restrictions (Snow et al., 2021). Compared to the previous pandemic , the COVID-19 virus spread very fast worldwide and is more contagious (Petrosillo et al., 2020). To control the spread of the virus, most of the countries decided to shut their borders. So, this pandemic affects the agriculture sector more adversely as compared to the previous pandemics. COVID-19

guidelines of wearing the mask, social distancing on the public and workplace reduce the free movement of people. The agriculture sector's labour supply was hit hard in COVID-19 due to health and safety guidelines and border closure.

COVID-19 tracing application and quick response (QR) codes were used on agriculture farms to record employees and visitors on premises and alert the person if he or she visits the infected location. Information technology can intervene by addressing these challenges in the agriculture sector. (Parkin et al., 2021). In the past technologies such as tracing applications and QR code has been used in agriculture. However, their use has been primarily limited to the production systems where agricultural resources and products are tracked and traced using QR codes (Hu et al., 2013; Tarjan et al., 2014). Varallyai (2012) discuss the many applications of QR codes in the area of agriculture. Such QR codes are used to explain the features of the plants to the customers. The QR codes were used to educate the customers on how to handle those dangerous plants. In the past researches, the QR codes were used to communicate the various feature of the product to the customers like the type of fruit, timing of the fruit picking and packaging, take the customers to the company website, social media page, offer any sales discount offers etc. (Tarjan et al., 2014). However, the COVID-19 pandemic is unique in that the use of QR codes has been extended to the area of agricultural labour health and safety. This clearly shows the agriculture sector used Quick Response (QR) codes in a new way to continue the business process even in the pandemic.

Before COVID-19, the IoT application was used in the various agriculture process, as shown below in Figure 11. More than half of these applications were used primarily in the Irrigation, temperature, soil and humidity monitoring systems. These applications also monitor the Air, disease and fertilizer used for production (Farooq et al., 2020).

Figure 5.1 *IoT Agriculture Applications*

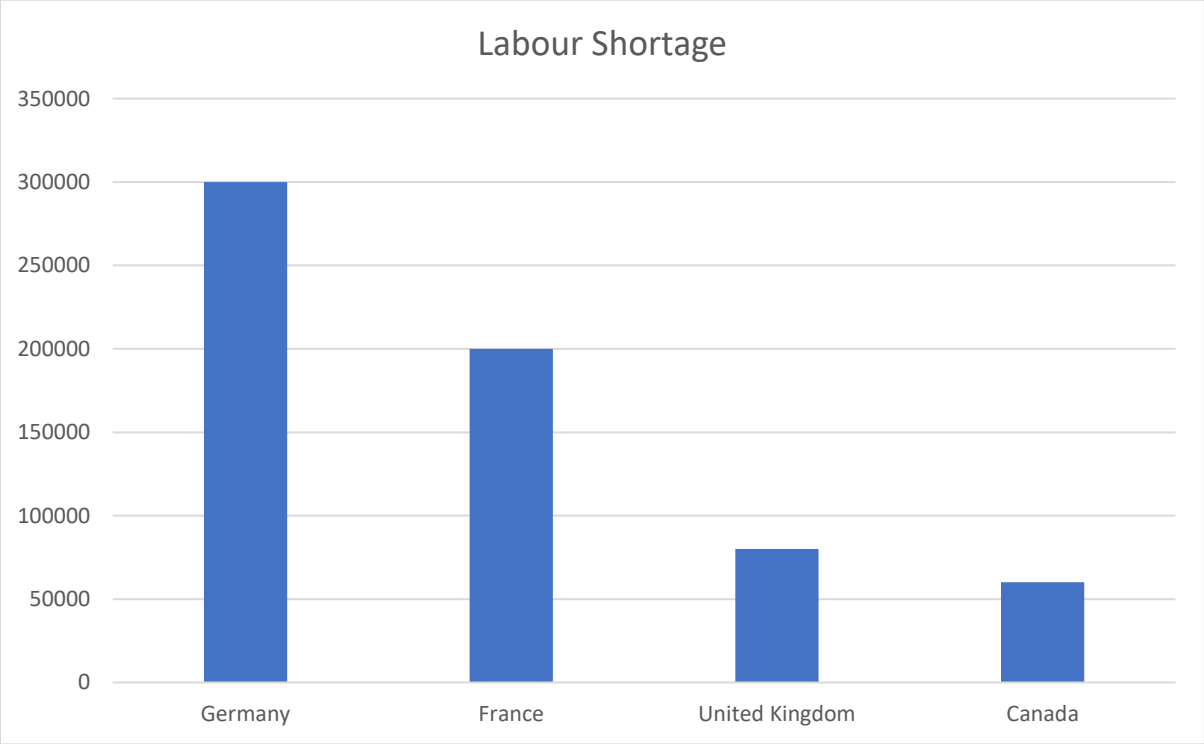


These IoT applications were used in the agriculture sector to trace, monitor and control the food safety and quality of the product. This feature of information technology in the agriculture sector played a significant role in the pandemic outbreak. During the COVID-19, the fear of transfer of virus through the food import and export. Most business organisations used that existing technology at a significant level to control the spread of the virus. In COVID world IoT's capability to generate and transport data without requiring human intervention can be useful in controlling the virus in agricultural workers. COVID-19 standards recommend social distancing, masking, and working with fewer people on the job. All of these standards can be followed, and agriculture activity can continue through the use of IoT. The data generated and transferred will also improve the decision-making process (Farooq et al., 2020; Sharma & Kumar, 2021).

As shown in Figure 12 below, developed countries such as Germany, France, UK and Canada were struggling for agriculture farm workers (Ramakumar, 2020). In the above Figure, we see how the IoT was used in agriculture, mainly for the Irrigation, temperature, soil and humidity monitoring systems. COVID-19 condition of labour shortage put pressure on the agriculture sector stakeholders to think about a more innovative and digital farm business model. As we saw, the IoT can play a significant role in continuing the agriculture process even in the

pandemic. The use of technology will combat the spread of the virus. Information technology also helps in workers' health and safety during the time of COVID-19. In the short run, this looks like a capital-intensive decision for the agriculture sector. But in the long run, it improves agriculture's efficiency and productivity and makes the agriculture sector more resilient for future pandemics.

Figure 5.2 *COVID-19 and Labour Shortage in Developed Countries*



5.2 Consumer buying behaviour and IT intervention

The relationship between consumer behaviour and the quality of agricultural products generally has interested researchers. For example, Mowat and Collins (2000) study the consumer responses to the quality of persimmon in New Zealand & Australia and how analyzing these responses results in a more informed agricultural supply chain. However, the impact of pandemics on consumer behaviour has been limited, despite the fact that some studies have been conducted on the subject. According to Lobb et al. (2006), consumption patterns and purchasing behaviour were badly impacted during the pandemic.

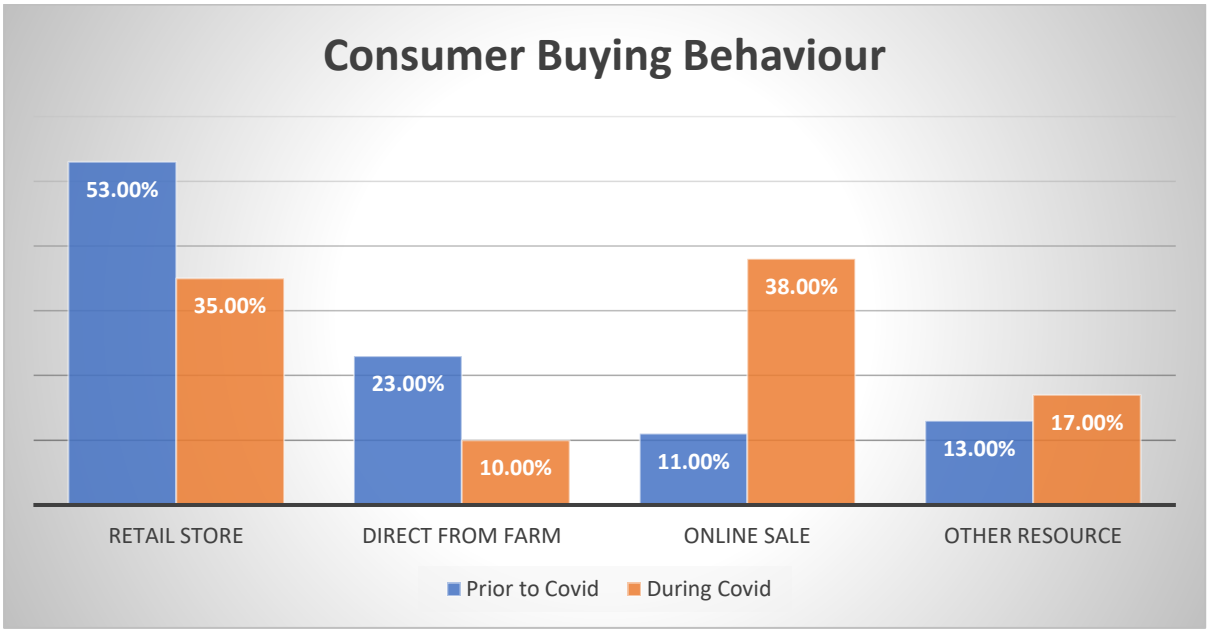
In past influenza pandemic studies, it has been found that consumers stopped buying specific goods for certain periods. For instance, in Vietnam, during Avian Influenza, consumers did not stop buying chicken, or there was no food buying panic among the people during that pandemic (Figuié & Fournier, 2008). In another study, it has been found that in Indonesia, the consumer buying channel shift from retail to the local market. This indicates that during the Avian influenza pandemic, consumers shifted towards the traditional way of buying food (Indrawan et al., 2018). However, COVID-19 is significantly different from these past pandemics in the sense that consumer buying behaviour shifted considerably from in-person to retail stores to online. The primary reason was the total lockdown decision by the governments to combat the spread of the virus.

The panic buying of food during past pandemics has not been observed to the same extent as during COVID-19. Qiu et al. (2018) explain that during the SARS outbreak in 2003, the panic among people was seen to buy drugs to prevent the disease. The panic buying mask was also seen to some extent. During the COVID-19 pandemic, however, there was a lot of fear and panic about buying food and masks and hand sanitisers (Naeem, 2020).

Social distancing rules had an impact on consumer buying behaviour. At the beginning of the pandemic, people panicked about stock supply, hence stockpiling. One potential area where information technology has intervened relates to online shopping. Online buying applications increased during COVID-19 (Li et al., 2020). Most people in developed countries where COVID-19 had hit tended towards online buying. For instance, in the USA, online grocery sales almost double in April 2020 compared to August 2019 (Ben Hassen et al., 2020). In China, people buying directly from the farmers reduced substantially from 23% to 10%.

On the other hand, consumers buying food online increased from 11% before COVID-19 to 38% during the outbreak (Li et al., 2020). An increase in online buying has also impacted other dependent areas such as inventory tracking. These trends clearly show the importance of information technology in the sales and purchase of agricultural produce, especially in panic buying in pandemics.

Figure 5.3 *COVID-19 and Consumer Buying Behaviour*



The Figure 5.3 above shows that trend of online buying applications increased during the time of the pandemic. As also seen in Indonesia from 2019 to 2020, online trade products grew from 3,124 to 15,019, which is a wobbling 380% increase. It indicates that information technology was probably an already widely used mode or that businesses implemented mobile-friendly apps. With the pandemic, digital systems were already up and running, i.e., smooth receiving, picking, and packaging. As the COVID-19 pandemic continues in most of the world, it forecasts an extended online buying as a long-term solution. This trend may result in a new norm of consumer buying behaviour going forward.

Government and non-government organisations also used information technology appreciably as an intervention through various online applications such as Facebook and WhatsApp for public distribution of food to the needy during the global crisis. The usage of these IT platforms gave these organisations an avenue to identify community problems and implement solutions for the continuous supply of food and other necessities to the general public. As these proved to be successful during COVID-19, many organisations may utilise these or develop new applications.

5.3 Supply Chain and IT Intervention:

As seen in the past research studies, the supply chain of the agriculture inputs and agricultural produce was highly disrupted during the pandemics such as Ebola, H1N1 virus, Avian influenza. During these pandemics, the supply chain process did not run at total capacity. (Huff et al., 2015). During the COVID-19 lockdowns, there was a new pattern of panic buying and food hoarding among people, putting the supply chain system under pressure (Swinnen & Vos, 2021). Ge et al. (2016) discussed that the agricultural food supply system is already very complex because of the food safety, quality and time sensitivity. However, the COVID-19 pandemic's lockdown decision, on the other hand, makes it more complicated than the prior system.

According to previous studies, food loss, particularly perishable items such as fruit and vegetables, is already relatively high in the agriculture sector during the supply chain process. The main reasons behind this were lack of technology, traditional agricultural practices, lack of collaboration between the various phases of the supply chain process (Despoudi, 2021). But the pandemic lockdown and border closure is the new challenge to the agriculture supply chain process. The sector faces a loss in total revenue and decline in the quality of customer service due to the failure of the supply.

Previous studies discuss the goal of using information technology in the agriculture sector supply chain process. In that research, the main objective of information technology use in the agriculture supply chain was to improve efficiency and customer service in the short run. It gives the company a competitive advantage (Mahalik & Kim, 2016; Tai et al., 2020). But COVID-19 pandemic adds another objective to the agriculture supply chain process of food quality, safety and continuous availability to the end customers. As seen during the pandemic the food security was threatened. According to the researchers, the number of people suffering from malnutrition will rise from 690 million to 820 million by 2020 (Smith & Wesselbaum, 2020). In the COVID -19 pandemic, every sector was looking for new ways to cooperate to ensure that adequate food was available on everyone's plate (Swinnen & Vos, 2021). This includes strengthening and collaborating supply chain of agriculture inputs and finish products using modern digital technology tools.

Digital technology also plays a significant role in the delivery of foods during the pandemic lockdown. As we saw in the literature review and finding chapter, most restaurants, bar, and food eateries were closed at the pandemic's beginning. These businesses used several digital platforms such as food ordering and delivery applications to continue the food services delivery. The research studies found that the use of new digital technology in restaurants, bars and food eateries improves the efficiency and productivity of management and improves the quality of customer service (Antonella et al., 2021).

In May 2020, Amazon established a food delivery business model in India. Parallelly in China, more than a hundred thousand new companies adapt the food delivery services to continue their business. During the COVID-19 pandemic, food delivery apps not only assisted catering companies and restaurants in surviving and growing, but they also met consumers' demands for safety, cost-effective online food, and convenience (Kumar & Shah, 2021).
Before COVID-19, the customers were interested in the traceability information of the product. But during the COVID-19 crisis, people are more conscious of transparency, traceability and find out the people involved in the logistics process of their product. The businesses that are better in digital technology and data management are in a better position. It highlights the importance of digital technology for collaboration, communication and transparency in the pandemic. Mobile applications with smart tags were developed to get the product's tracking information and check the storage condition during the supply chain process (Paolo Visconti et al., 2020).

Automating various agricultural activities, such as the packing process in the pack house, reduces the health concerns associated with viral transmission during the COVID-19 supply chain and logistics process. The problem of hoarding and stock limitation has arisen as a result of the lockdown panic. However, if retailers invest in digital payments, E-commerce, and IoT apps, maintaining the critical supply chain will be resolved. It is important to recognise that being online is the future of any developed country, and thus the faster we embrace IoT, the easier it will be for us.

5.4 Summary

As seen in the above discussion, information technology plays an important role in combating the challenges in the area of labour shortage, supply chain, and buying behaviour (Eger et al., 2021; Li et al., 2020; Ponomarov & Holcomb, 2009; Ramakumar, 2020; Serafim et al., 2020; Singh et al., 2021). Based on these themes, I present a theoretical framework that can guide the agricultural – IT interventions during the pandemics.

This framework is presented as figure 5.4 below

Figure 5.4 *Theoretical Framework Guide the Agricultural – IT Interventions during the pandemics*

In this framework there are three stakeholders which are the focus of IT interventions namely the agricultural customers, the labour, and the agricultural supply chain participants. There are further subtypes of each of these stakeholders for example, agricultural customers are a broad category of the retail customers (such as vegetable and fruit purchasers) as well as the customers of agricultural input resources (fertilisers, machinery, etc.). Similarly, the labour can include sub type such as farm labour, contractors, specialists, etc. The supply chain

stakeholders may be of the type such as agricultural resource providers, retailers, etc. Organisations can assess the importance levels of the stakeholder sub types in the three area of labour, supply chain and customer, and then their IT interventions as shown in table 5.1 below.

Table 5.1 *IT – agricultural stakeholder importance matrix*

Themes	Stakeholder Categories	Examples of Stakeholder Sub-types	Example of Importance level
Labour Supply Issues	Labour	Farm Labour	High
		Contractors (such as Horticultural Specialists)	Medium
Supply Chain Issues	Supply Chain Participants	Food Retailers	High
		Agricultural Resource Providers (such as pesticide or seed providers)	Medium
Customer Purchasing Behaviour	Agricultural Customers	Food and Vegetable Consumers	High
		Farm Equipment Consumers	Medium

Chapter 6 : Conclusion

6.1 Chapter preview

This chapter first explains the research purpose of this study. Secondly, it describes key findings discovered through a qualitative method, i.e., thematic analysis, to find answers to the two main research questions. Then, thirdly explain the theoretical and practical contribution of this research. Finally, based on the research outcome and research method, this chapter discuss the limitations of this research study and gives recommendations for future research.

6.2 Research purpose and key findings of the study

The first objective of this research is to find out the dominant discourses in the study of the COVID-19 impacts on horticulture. Secondly, it also seeks to identify the potential areas where information technology interventions can help meet the challenges of the horticulture industry.

The two main research questions that this dissertation is intended to answer are as:

Q.1 What are the dominant discourses in the study of the impacts of COVID-19 on horticulture?

Q.2 What are the potential areas of information technology interventions in horticulture in the post COVID world?

In this dissertation, I used the qualitative method, i.e., thematic analysis. By using this research method, the main themes emerged as: (1) Farmer lockdown experience; (2) Horticulture, Digital transformation and COVID-19; (3) Low productivity and urgent need of technology adoption; (4) Other themes. I used the relationship between these main themes and sub-themes that emerged from thematic analysis to provide this research-study findings that add to our understanding of the COVID-19 dilemma. This research study will provide answers to fill the research knowledge gap in the agricultural sector.

According to the findings of this research study, the horticulture sector faces various challenges during this pandemic. This can be summarised as below:

COVID-19 impact on the horticulture Industry

1. Agriculture labour shortage due to lockdowns and border closure decisions to control the spread of the virus.
2. Supply chain disruption of agriculture inputs.
3. Overall productivity and efficiency of the sector reduce in the period of COVID-19.

COVID-19 disrupted the agricultural production process significantly. To address this, the sector's business model must be altered. During the COVID pandemic, most agriculture sector stakeholders strive to use information technology in their business processes. Information technology plays a significant role in the horticulture sector during the pandemic. This research study also shows how information technology intervenes to resolve issues namely, labour shortage, supply chain and distribution, and consumers demand in the COVID lockdown. As IoT applications, online buying applications play a significant role in the food supply continuity in lockdowns.

6.3 Theoretical & practical contribution

The theoretical contribution of this study is to discover new challenges in the horticulture industry. It was significant to identify how the pandemic affected the sector and how digital technology helped deal with challenges during the COVID-19 crisis. Previous pandemics affected the horticulture sector, but lockdown decisions and border closure are new knowledge to the existing studies. This study is unique because it provides a thorough understanding of how COVID-19 affects the horticulture sector and how information technology plays a role in addressing agricultural sector issues. The association between COVID-19 horticultural challenges and information technology intervention to address these difficulties was investigated in this study. In this research, peer-reviewed research articles literature were used to determine the dominant discourses in the impact of COVID-19 on the horticulture industry. Following an analysis of the findings, this research answers the research question and attempts to fill a research gap in the agricultural industry. This study adds to the literature on potential

areas of information technology interventions in horticulture to address the challenges that the horticulture sector faces as a result of the COVID pandemic.

The most significant contribution of this research is providing guidelines to the sector on how information technology can assist the sector in the post COVID recovery plan and any subsequent crises in the future. The findings from this research study demonstrate that COVID-19 negatively impacts agriculture operations and makes it difficult to carry out daily activities.

Existing studies on pandemic do not provide a framework for implementing information technologies in agricultural/ horticulture. On important contribution of this study is that it provides a framework for implementing information technology interventions in agriculture during the times of pandemic. For example, agricultural IT implementation during pandemic can address the areas of labour supply, supply chain, and customer purchasing. This framework can help the IT teams, within the public and corporate sector, during the pandemic, to focus their efforts on these three themes.

6.4 Limitation of the research

There was little literature available about the horticulture sector's experience with the COVID-19 pandemic, and due to its current situation, the research area is relatively new in this field. As a result, the availability of information technology and economic and social conditions in developing countries differ from developed countries. The findings of this research, therefore, cannot be generalised to every country. To that end, more in-depth research is required based on the specific conditions of the countries. This shall be based on a small body of work that focuses on the horticultural industry's experience with the COVID-19 outbreak. The pandemic impact on the horticulture sector research is ongoing due to the COVID still being active in most parts of the world. Thus, the ongoing COVID-19 may bring a new and unexpected challenge in the later stages.

6.5 Future research possibilities

This study is limited to qualitative secondary data, so in the future, the researcher could conduct the study by interviewing farmers and asking them about their experiences with COVID-19.

Future research can compare the findings to the current research response to the COVID-19 to obtain more diverse solutions to manage this type of crisis in the future.

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Annexure:

Author (Year)	Title of Research Paper	Initial codes
Agyei et al., (2021)	*COVID-19 and food prices in sub-Saharan Africa*	• Food inflation COVID-19 and food security • COVID-19 disturb the food supply system.
Akhmadi et al., (2021)	*Online marketing of food products through marketplace platform: A study of community based online marketplace of bedukmutu*	• Online marketing • eMarketing
Anshari et al., (2019)	*Digital marketplace and fintech to support agriculture sustainability*	• Digital platform for financial transaction in agriculture, • More transparency, customers can compare product prices and quality etc.
Antonella et al. (2021)	*Innovative digital technologies for purchasing and consumption in urban and regional agro-food systems: A systematic review*	• E-commerce trend increased in pandemic • Food buying apps, healthy lifestyle and COVID-19
Ben Hassen et al., (2020)	*Impact of COVID-19 on Food Behavior and Consumption in Qatar*	• panic for stockpiling the food during COVID-19
Bochtis et al., (2020)	*Agricultural workforce crisis in light of the COVID-19 pandemic*	• Lockdown decision • Migrant agriculture labour shortage • Harvesting season disrupted

Carmela Annosi, M et al. (2020)	*Digitalization in the agri-food industry: the relationship between technology and sustainable development*	• COVID -19 and significance of Digitisation of agriculture. • Challenges sector face in adoption of technology.
Chavas & Nauges, (2020)	*Uncertainty, Learning, and Technology Adoption in Agriculture*	• Farmer welfare and technology adoption • Information technology and agricultural productivity and efficiency
Chenarides et al. (2021)	*COVID-19 impact on fruit and vegetable markets: One year later*	• Producer sharing, • Some developed countries show resiliency in supply chain system • Food threat varies from countries to countries
Devereux et al. (2020)	*Conceptualising COVID-19's impacts on household food security*	• COVID-19 guideline • Closed food markets, • Food insecurity.
Di Vaio et al., (2020)	*Artificial intelligence in the agri-food system: Rethinking sustainable business models in the COVID-19 scenario.*	• IT in operational process • Improve production and efficiency
Hemming et al., (2020)	*Cherry tomato production in intelligent greenhouses-sensors and AI for control of climate, irrigation, crop yield, and quality*	• digital technology and product quality, • Automation and agriculture production.
Kumar et al. (2021)	*Mitigate risks in perishable food supply chains: Learning from COVID-19*	• Using digital technology to control COVID-19 risk, • COVID-19 impact farmer, customers and logistic and supply chain.
Larue, B. (2020)	*Labor issues and COVID-19*	• Agriculture Labour availability issue • Cost of production increased due to labour shortage.

Li, J., et al. (2020)	*Changing grocery shopping behaviours among Chinese consumers at the outset of the COVID-19 outbreak*	• Food shopping behaviour change in COVID-19 • Customers struggle in COVID-19
Middendorf, B. J. et al. (2021)	*Smallholder farmer perceptions about the impact of COVID-19 on agriculture and livelihoods in Senega*	• COVID-19 and farm well-being • Farmers income decline during that pandemic.
Naeem, Muhammad (2020)	*Understanding the customer psychology of impulse buying during COVID-19 pandemic: implications for retailers*	• Fear of COVID-19 change the buying behaviour, • Customers start buying online • Technology use increase.
Neef, A. (2020)	*Legal and social protection for migrant farm workers: lessons from COVID-19*	• Labour shortage in COVID-19 • health check on workplace • COVID-19 guideline for safe workplace.
Nitturkar, H. (2021)	*A practical tool to enhance the chances of success of digital agriculture interventions for sustainable development in Africa and India*	• COVID -19 and inclusive and sustainable agriculture
O'Hara et al., (2021)	*COVID-19's impact on farmers market sales in the Washington, DC*	• Food sales impacted by COVID-19 • Food market closed due to COVID-19
Pannell & Claassen, (2020)	*The Roles of Adoption and Behavior Change in Agricultural Policy*	• Innovation in agriculture • New way of doing agriculture

Ponomarov & Holcomb, (2009)	*Understanding the concept of supply chain resilience*	• Resilience of food supply chain in disturbance.
Priyadarshini, P., & Abhilash, P. C. (2021)	*Agri-food systems in India: Concerns and policy recommendations for building resilience in post COVID-19 pandemic times*	• Food security • Sustainable food system
Ramakumar, R. (2020)	*Agriculture and the Covid-19 Pandemic: An analysis with special reference to India*	• Agriculture labour shortage • Logistics and transport system struggled
Redman, R. (2020)	*Online grocery to more than double market share by 2025*	• Online buying behaviour AND COVID -19
Saha & Bhattacharya, (2020)	*Consequence of lockdown amid COVID-19 pandemic on Indian agriculture*	• Farm labour shortage • Harvesting schedule interrupted • Production reduce.
Serafim et al., (2020)	*Perspectives from CO+RE: How COVID-19 changed our food systems and food security paradigms*	• healthy food in COVID-19, • COVID-19 disrupt entire food system. • Food security threat due to pandemic
Siddiquei & Khan, (2020)	*COVID 19: challenges for vegetable production in India*	• Food supply negatively affected by COVID-19 • Labour shortage in agriculture sector
Shrestha et al., (2020)	*The impact of COVID-19 on globalization.*	• Production of agriculture reduce in COVID-19 • Demand shock the global trade in COVID-19

Shruthi & Ramani, (2020)	*Statistical analysis of impact of COVID 19 on India commodity markets*	• Farm agriculture inputs shortage • Cost of production increased during pandemic.
Singh et al. (2021)	*Impact of COVID-19 on logistics systems and disruptions in food supply chain*	• COVID-19 pandemic disrupt logistic and supply chain system, • Food security threatened in lockdowns.
Smith & Wesselbaum, (2020)	*COVID-19, Food Insecurity, and Migration*	• Migration effect by food security • COVID-19 put more pressure on food security
Swinnen & Vos, (2021)	*COVID-19 and impacts on global food systems and household welfare: Introduction to a special issue*	• Food insecurity and COVID-19 • Supply chain and information technology
Thilmany et al., (2020)	*Local food supply chain dynamics and resilience during COVID-19*	• Agriculture resilience reduce supply chain disruption in COVID-19 • Collaboration of various stage of supply chain improve food safety
V. Snow et al., (2021)	*Resilience achieved via multiple compensating subsystems: The immediate impacts of COVID-19 control measures on the agri-food systems of Australia and New Zealand*	• Farmer use information technology for virtual meeting in COVID-19 • Online transaction increased in fertilizer sale • Online data sharing for decision making in COVID-19
Weersink et al., (2021)	*COVID-19 and the agri-food system in the United States and Canada*	• Vulnerable agriculture supply chain system • Trend of agriculture automation on rise