ECONOMICS OF HIGH TECH FARMING IN KERALA: AN EXPLORATIVE ANALYSIS OF GREENHOUSE VEGETABLE FARMS

Thesis Submitted to the
UNIVERSITY OF CALICUT
For the award of the Degree of
DOCTOR OF PHILOSOPHY IN ECONOMICS

By

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2023

DECLARATION

I, **Ashraf Panancheri,** hereby declare that this dissertation titled ***"Economics of High tech Farming in Kerala: An Explorative Analysis of Greenhouse Vegetable Farms"*** is the outcome of my own study undertaken under the guidance of **Dr. Sanathanan Velluva, HoD and Associate Professor (Retd),** and Co- Guidance of **Dr. Shiby M Thomas, HoD and Associate Professor, PG and Research Department of Economics, St. Joseph's College (Autonomous) Devagiri, Calicut.** It has not previously formed the basis for awarding any degree, diploma, or certificate of this institute or any other institute or university. I have duly acknowledged all the sources used by me in the preparation of this thesis.

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This is to certify that the dissertation titled ***"Economics of High tech Farming in Kerala: An Explorative Analysis of Greenhouse Vegetable Farms"*** is the record of the original work done by Mr. **Ashraf Panancheri** under my guidance and supervision. The results of the research presented in this thesis have not previously formed the basis for the award of any degree, diploma, or certificate of this institute or any other institute or university.

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This is to certify that the document herein the thesis entitled **"Economics of High Tech Farming in Kerala: An Explorative Analysis of Greenhouse Vegetable Farms"** submitted by Mr. Ashraf Panancheri to the University of Calicut under my guidance. No corrections or modifications have been recommended by the adjudicators in the thesis. Further certified that the contents in the thesis and the soft copy are one and the same.

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ACKNOWLEDGMENT

This is the final stretch of a very busy, very challenging, very interesting quest to realize one of my aspirations. It occurs to me that it would be inadequate if I did not express my deepest, most sincere appreciation to all those who helped make this endeavor a reality. All people from many walks of life provided encouragement, advice, and constructive criticism that helped shape this dissertation into its final form. I would like to express my sincere gratitude to each and every one of them.

My utmost appreciation goes to ***Dr. Sanathanan Velluva****, who has been both my guide and my research supervisor. With his wise counsel and unwavering encouragement, I found conducting this research to be a truly engaging intellectual endeavour. He had faith in my skills and relied on me to complete this task. His technical knowledge and zeal were crucial to the successful completion of this dissertation. I can't thank him enough for his careful and thorough guidance.*

Second, I would want to express my eternal thanks to ***Dr. Shiby M. Thomas****, Associate Professor and Head of the Department of Economics at St. Joseph's College Devagiri, who has been both my mentor and co-guide throughout my time here after my supervisor retired. He provided me with invaluable advice and unwavering support, allowing me to continue my research. Despite his hectic schedule, he always made time to assist me to complete the necessary formalities.*

I am always thankful to ***Dr. Asha Mathew*** *(Assistant Professor of Economics, St Joseph‟s College, Devagiri) for showing interest in my work and offering critical comments at various stages. I am thankful to the other faculty members of the Department of Economics,* ***Fr. Anto N J,*** *and* ***Dr. (Fr) Biju Joseph,*** *and* ***Prof: Thomachan KT*** *for showing interest in my work and offering critical comments at various stages.*

I am grateful to the members of my Research Advisory Committee, ***Dr. K.X. Joseph, Dr. K.R. Ranjini, Dr. Baby Chacko, Dr. Abdul Saleem A., Dr. T.K.***

Muraleedharan, Dr. Shabeer KP, Dr. Rammiya Rajan, Dr. Anjaly Jose, Dr. Abraham Joseph, and Dr. Sanoop MS, *for their valuable suggestions and guidance.*

I offer my sincere thanks to ***Dr. Sibichen M Thomas****,* ***Dr. Jose John Mallikassery Dr. Sabu K Thomas*** *(Former Principals of Devagiri College) and* ***Dr. Boby Jose*** *(Principal) for their encouragement and valuable support which have been immensely helpful while completing this research work. I extend my sincere thanks to* ***the Principal Agricultural Officers*** *of 14 districts of the Kerala state, who helped me to collect addresses and basic details of high-tech farmers from whom I collected the primary data for this research. Further, I extend my deep gratitude to* ***Mr. Abdulla Kadengal****, who helped me to collect the primary data from the hi-tech farmers scattered all over the state. Without his support, I wouldn't be able to complete this endeavour. I express my special thanks to my fellow researchers* ***Dr. Sujin, Mrs. Radeena, Mrs. Esta Martin, Dr. Jasna, Miss. Irfana, Mr. Mohammed Saleem, Mr. Sebastian and Mrs. Deepa*** *for their invaluable support and assistance throughout my research. I am also indebted to the department of collegiate education, Government of Kerala, for granting me permission to pursue part-time research.*

I am grateful to the authorities of Government College, Malappuram for providing me the opportunity to pursue the research. I place my deep gratitude to ***Dr. Kadeeja P*** *(Principal), and my colleagues* ***Dr. Suprabha, Dr. Hyderali K,*** *Dr.* ***Basheer P, Mrs. Greeshma H, Mrs. Sabira A, Dr. Abdul Sameer PM, and Mr. Sajeev U and Mr. Ismail P.*** *Further, I express my gratitude towards* ***Mr. Rajesh P*** *(Govt. Engineering College Thrissur) for his support and encouragement.*

Obviously, my family's unwavering support and unending encouragement were crucial to my completion of this thesis. I owe my boundless enthusiasm and optimism for this study effort to the unwavering love, care, and devotion of my mother, wife, sons, and daughter. They bravely bore the hardships associated with my pursuit of higher education and gave me the means and motivation to complete this task.

This Ph.D thesis, "Economics of High-tech Farming in Kerala: An Explorative Analysis of Greenhouse Vegetable Farms", would not have been possible without the generous assistance, cooperation, and direction of many highly respected individuals. I would like to provide my deepest appreciation to everyone involved.

Finally, I want to thank God for benefiting me in the ways that have been mentioned.

Thank you all..........

Dedicated to

My Parents and Teachers

ECONOMICS OF HIGH-TECH FARMING IN KERALA: AN EXPLORATIVE ANALYSIS OF GREENHOUSE VEGETABLE FARMS

ABSTRACT

Kerala launched high-tech vegetable cultivation in greenhouses (GH) in 2009–10, but it failed to gain widespread adoption among farmers. This study aimed to provide a comprehensive economic analysis of this farming method in the state. Specifically, the study examined the extent of greenhouse cultivation, the socio-economic features of greenhouse farmers, unit costs, revenue, and profit, as well as techno-economic constraints. The findings of this study provide valuable insights for policymakers and farmers on how to promote the adoption of high-tech vegetable cultivation in the state.

This study was based on both primary and secondary data. Secondary data were collected from district-level principal agricultural offices, various issues of Economic Review, the database of the EPW Research Foundation, published articles and official reports. Primary data was collected from 165 GH farmers from all over the state through interactive personal interviews. Non-parametric tests like chi-square, Mann-Whitney U, Kruskal-Wallis, Spearman's rho, and Mc Nemar's test were used to analyse data. Regression models were used to determine production function and cost-output elasticity, while a logit model was used to identify significant factors affecting profit earning.

Despite generous government subsidies, high-tech vegetable cultivation in greenhouses has a negligible impact on the state's vegetable production, accounting for only 37 hectares of the total vegetable cultivation area. Greenhouse farming in Kerala is a semi-tech activity, with no significant difference in annual output across different social characteristics. However, full-time farmers and sufficiently trained farmers have significantly higher annual average output than part-time farmers and untrained or insufficiently trained farmers, respectively. The most popular greenhouse crops in Kerala were yardlong beans, salad cucumbers, and tomatoes. The Cobb-Douglas-type production function of GH cultivation revealed an increasing return to scale (1.154). The benefit-cost ratio (BCR) of GH farming in Kerala was low (0.715 without subsidy and 1.1 with subsidy). The logit model revealed that full-time activity, contracts with traders, better prices, experience, type of ventilation, and regular visits of agricultural officers were the major determining factors in categorising the farms as profit earners. {The model was statistically significant [χ^2 (12, N = 165) =119.508, $p<0.001$]. The model explained 84.1% (Nagelkerke R square) and correctly classified 95.2%}. The principal technical challenges of GH farming were pest infestation, limited glazing sheet durability, a lack of scientific disposal of used glazing sheets, and inadequate pollination strategies. The major economic constraints of GH farming in the state included unsold products, insufficient prices, merchants' attempts to reduce prices, a lack of government support for marketing, heavy debt, delayed subsidies, and a lack of insurance coverage for crops.

These findings suggest that high-tech vegetable cultivation in greenhouses has the potential to increase vegetable production in Kerala, but more needs to be done to promote its adoption among farmers. This could include providing additional training and support to farmers, as well as addressing the techno-economic constraints that are currently limiting its adoption.

Key Words: High-tech farming, Greenhouse farming, Polyhouse farming, Economic viability of greenhouse farming, Techno-economic constraints of Greenhouse farming.

കേരളത്തിലെ ഹൈ ടെക് കൃഷിയുടെ സാമ്പത്തികശാസ്ത്രം: ഹരിതഗൃഹ പച്ചക്കറി ഫാമുകളുടെ ഒരു പര്യവേക്ഷണ വിശകലനം

സംഗ്രഹം

കേരളം 2009-10 ൽ ഹരിതഗൃഹങ്ങളിൽ (ഹ.ഗൃ) ഹൈ-ടെക് പച്ചക്കറി കൃഷി ആരംഭിച്ചു, എന്നാൽ ഇത് കർഷകർക്കിടയിൽ വ്യാപകമായി സ്വീകരിക്കപ്പെട്ടില്ല. ഈ കൃഷിരീതിയുടെ സമഗ്രമായ സാമ്പത്തിക വിശകലനം നൽകുന്നതിനാണ് ഈ പഠനം ലക്ഷ്യമിട്ടത്. പ്രത്യേകിച്ചും, ഹ.ഗൃ കൃഷിയുടെ വ്യാപ്തി, കർഷകരുടെ സാമൂഹിക-സാമ്പത്തിക സവിശേഷതകൾ, യൂണിറ്റ് ചെലവ്, വരുമാനം, ലാഭം, സാങ്കേതിക-സാമ്പത്തിക പരിമിതികൾ എന്നിവ പഠനം പരിശോധിച്ചു. ഈ പഠനത്തിന്റെ കണ്ടെത്തലുകൾ, സംസ്ഥാനത്ത് ഹൈ-ടെക് പച്ചക്കറി കൃഷിയുടെ സ്വീകാര്യത പ്രോത്സാഹിപ്പിക്കുന്നതിനെക്കുറിച്ച് നയരൂപീകരണക്കാർക്കും കർഷകർക്കും വിലപ്പെട്ട അറിവുകൾ നൽകുന്നു.

ഈ പഠനം പ്രാഥമികവും ദ്വിതീയവുമായ ഡാറ്റയെ അടിസ്ഥാനമാക്കിയുള്ളതാണ്. ജില്ലാതല പ്രിൻസിപ്പൽ കൃഷിഓഫീസുകൾ, ഇക്കണോമിക് റിവ്യൂവിന്റെ വിവിധ ലക്കങ്ങൾ, ഇപിഡബ്ല്യു റിസർച്ച് ഫൗണ്ടേഷന്റെ ഡാറ്റാബേസ്, ഔദ്യോഗിക റിപ്പോർട്ടുകൾ, പ്രസിദ്ധീകൃത കൃതികൾ എന്നിവയിൽ നിന്ന് ദ്വിതീയ ഡാറ്റ ശേഖരിച്ചു. സംവേദനാത്മക വ്യക്തിഗത അഭിമുഖങ്ങളിലൂടെ സംസ്ഥാനത്തുടനീളമുള്ള 165 ഹ.ഗൃ കർഷകരിൽ നിന്ന് പ്രാഥമിക വിവരങ്ങൾ ശേഖരിച്ചു. chi-square, Mann-Whitney U, Kruskal-Wallis, Spearman's rho, Mc Nemar's test തുടങ്ങിയ നോൺ-പാരാമെട്രിക് ടെസ്റ്റുകൾ ഡാറ്റ വിശകലനം ചെയ്യാൻ ഉപയോഗിച്ചു. ഉൽപ്പാദന പ്രവർത്തനവും ചെലവ്-ഉല്പന്ന ഇലാസ്തികതയും നിർണ്ണയിക്കാൻ റിഗ്രഷൻ മോഡലുകൾ ഉപയോഗിച്ചു, അതേസമയം ലാഭ-വരുമാനത്തെ ബാധിക്കുന്ന പ്രധാന ഘടകങ്ങളെ തിരിച്ചറിയാൻ ലോജിറ്റ് മോഡൽ ഉപയോഗിച്ചു.

ഈ സംരംഭത്തിന് സർക്കാർ ഉദാരമായി സബ്സിഡി നൽകിയെങ്കിലും സംസ്ഥാനത്തിന്റെ പച്ചക്കറി ഉൽപ്പാദനത്തിൽ അതിന് യാതൊരു സ്വാധീനവുമില്ല. ഏകദേശം 37 ഹെക്ടറിൽ മാത്രമാണ് ഈ രീതി പിന്തുടരുന്നത്. പച്ചക്കറി കൃഷിയുടെ ആകെ വിസ്തൃതിയുടെ വളരെ നിസ്സാരമായ ഒരു ഭാഗമാണിത്. വിവിധ സാമൂഹിക സവിശേഷതകളിൽ വാർഷിക ഉൽപ്പാദനത്തിൽ കാര്യമായ വ്യത്യാസമില്ലാതെ സംസ്ഥാനത്തെ ഹ.ഗൃ കൃഷി ഒരു സെമി-ടെക് പ്രവർത്തനമാണെന്ന് പഠനം കണ്ടെത്തി. എന്നിരുന്നാലും, പാർട്ട്-ടൈം കർഷകരെ അപേക്ഷിച്ച് മുഴുവൻ സമയ കർഷകർക്കും പരിശീലനമില്ലാത്ത അല്ലെങ്കിൽ വേണ്ടത്ര പരിശീലനം ലഭിച്ചിട്ടില്ലാത്ത കർഷകരെ അപേക്ഷിച്ച് മതിയായ പരിശീലനം ലഭിച്ച കർഷകർക്കുമിടയിൽ വാർഷിക ശരാശരി ഉൽപാദനത്തിലെ വ്യത്യാസം

പ്രകടമാണ്. കേരളത്തിലെ ഏറ്റവും പ്രചാരമുള്ള ഹ.ഗ്ര വിളകൾ നീളൻ പയറും സാലഡ് വെള്ളരിയും തക്കാളിയും ആയിരുന്നു. ഹ.ഗ്ര കൃഷിയുടെ കോബ്-ഡഗ്ലസ്-ടൈപ്പ് പ്രൊഡക്ഷൻ ഫംഗ്ഷൻ റിട്ടേൺ ടു സ്കെയിൽ 1.154 ആണെന്ന് കണ്ടെത്തി. കേരളത്തിലെ ഹ.ഗ്ര കൃഷിയുടെ ആനുകൂല്യ-ചെലവ് അനുപാതം (ബിസിആർ) കുറവായിരുന്നു (സബ്സിഡി ഇല്ലാതെ 0.715, സബ്സിഡിയോടെ 1.1). മുഴുവൻ സമയ പ്രവർത്തനം, വ്യാപാരികളുമായുള്ള കരാറുകൾ, മികച്ച വില, അനുഭവപരിചയം, വെന്റിലേഷൻ തരം, കൃഷി ഓഫീസർമാരുടെ പതിവ് സന്ദർശനം എന്നിവയാണ് ഫാമുകളെ ലാഭകരമെന്ന് തരംതിരിക്കുന്നതിനുള്ള പ്രധാന നിർണ്ണായക ഘടകങ്ങൾ എന്ന് ലോജിറ്റ് മോഡൽ വെളിപ്പെടുത്തി. [χ^2 (12, N = 165) =119.508, p<0.001]. മോഡൽ 84.1% (നാഗെൽകെർകെ R^2) വിശദീകരിക്കുകയും 95.2% കൃത്യമായി തരംതിരിക്കുകയും ചെയ്തു. കീടബാധ, മേച്ചിൽഷീറ്റുകളുടെ പരിമിതമായ ഈടുനിൽക്കൽ, ഉപയോഗിച്ച മേച്ചിൽഷീറ്റുകളുടെ ശാസ്ത്രീയ നിർമാർജനത്തിന്റെ അഭാവം, അപര്യാപ്തമായ പരാഗണ തന്ത്രങ്ങൾ എന്നിവയാണ് ഹ.ഗ്ര കൃഷിയുടെ പ്രധാന സാങ്കേതിക വെല്ലുവിളികൾ. വിറ്റഴിക്കാൻ കഴിയാത്ത ഉൽപ്പന്നങ്ങൾ, അപര്യാപ്തമായ വില, വില കുറയ്ക്കാനുള്ള വ്യാപാരികളുടെ ശ്രമങ്ങൾ, വിപണനത്തിനുള്ള സർക്കാർ പിന്തുണയുടെ അഭാവം, കനത്ത കടഭാരം, കാലതാമസം നേരിടുന്ന സബ്സിഡികൾ, വിളകൾക്ക് ഇൻഷുറൻസ് പരിരക്ഷയുടെ അഭാവം എന്നിവ സംസ്ഥാനത്തെ ഹ.ഗ്ര കൃഷിയുടെ പ്രധാന സാമ്പത്തിക പരിമിതികളിൽ ഉൾപ്പെടുന്നു.

ഈ കണ്ടെത്തലുകൾ കേരളത്തിൽ ഹരിതഗൃഹങ്ങളിലെ അത്യാധുനിക പച്ചക്കറി കൃഷി വർദ്ധിപ്പിക്കാനുള്ള സാധ്യതയുണ്ടെന്ന് സൂചിപ്പിക്കുന്നു, പക്ഷേ കർഷകർക്കിടയിൽ ഇതിന്റെ സ്വീകാര്യത പ്രോത്സാഹിപ്പിക്കുന്നതിന് കൂടുതൽ ചെയ്യേണ്ടതുണ്ട്. ഇതിൽ കർഷകർക്ക് അധിക പരിശീലനവും പിന്തുണയും നൽകുന്നതും നിലവിൽ ഇതിന്റെ സ്വീകാര്യത പരിമിതപ്പെടുത്തുന്ന സാങ്കേതിക-സാമ്പത്തിക പരിമിതികൾ പരിഹരിക്കുന്നതും ഉൾപ്പെടുന്നു.

സൂചക പദങ്ങൾ: ഹൈ ടെക് കൃഷി, ഹരിതഗൃഹ കൃഷി, പോളിഹൌസ് കൃഷി, ഹരിതഗൃഹ കൃഷിയുടെ സാമ്പത്തിക സാധ്യത, ഹരിതഗൃഹ കൃഷിയുടെ സാങ്കേതിക സാമ്പത്തിക പരിമിതികൾ

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LIST OF ABBREVIATIONS

BCR	:	Benefit Cost Ratio
CEA	:	Controlled Environment Agriculture
CHD	:	Coronary Heart Disease
COFC	:	Conventional Open Field Cultivation
CVC	:	Conventional Vegetable Cultivation
EPW	:	Economic and Political Weekly
FAO	:	Food and Agriculture Organisation
FSSAI MRL	:	The Food Safety and Standards Authority of India, Maximum Residue Level
FSRS	:	Farming System Research Station
GDP	:	Gross Domestic Product
GH	:	Greenhouse
GI	:	Galvanised Iron
GVC	:	Greenhouse Vegetable Cultivation
Ha	:	Hector
HCG	:	High Tech Cultivation under Greenhouses
HDP	:	High Density Planting
HTR and TU		
HYV	:	High Yielding Variety
IARI	:	Indian Agri-Research Institute
IPM	:	Integrated Pest Management
IRR	:	Internal Rate of Return
KCAET	:	Kelappaji College of Agricultural Engineering and Technology
KAU	:	Kerala Agriculture University

LE	:	Egyptian Pound
MSP	:	Minimum Support Price
MT	:	Metric Ton
NAAS	:	National Academy of Agricultural Sciences
NABARD	:	National Bank for Agriculture and Rural Development
NIN	:	National Institute of Nutrition
NHM	:	National Horticulture Mission
NPV	:	Net Present Value
NVP	:	Naturally Ventilated Poly house
PBP	:	Pay Back Period
PC	:	Protected Cultivation
PI	:	Profitability Index
PG	:	Plant Growth Regulator
RARS	:	Regional Agricultural Research Station
SMS	:	Short Message Service
SHG	:	Self-Help Group
Sq. m.	:	Square Meter
TFP	:	Total Productivity
UK	:	United Kingdom
USA	:	United States of America
USDA	:	US Department of Agriculture
UVSPS	:	Ultra-violet Stabilised Polythene Sheets
WHO	:	World Health Organisation

CHAPTER I
INTRODUCTION

1.1 Introduction

Kerala is one of the southern states of the Indian Union and has its own unique features and problems. Basically, it is a consumer state since its commodity production sector is weak and it resorts to other states for essential commodities. The production of food in general and vegetables in particular is not sufficient to meet the state's requirements. Kerala resorts to the neighbouring states for much of its vegetable and fruit requirements. The state imports around Rs. 1500 crore worth of vegetables a year from neighbouring states. In 2012, the state produced only 22 percent of the required vegetables (Varma, 2016). The state produced only 6.5 lakh metric tonnes of vegetables in 2016 and aimed to increase that to 9.5 lakh metric tonnes within two years (*The New Indian Express,* April 7, 2018). Nevertheless, it is worth noting that the state's whole yearly demand for vegetables amounted to around 30 lakh metric tonnes, of which only 40 percent was met by the total production (Suchitra, 2015). Most imported vegetables are contaminated with poisonous pesticide residues. A study conducted by the Pesticide Residue Analytical Laboratory of Kerala Agriculture University found that 5.4 percent of all the vegetables studied had pesticide residue. According to Gopinathan (2018), it was 7.6 percent for open-market samples and 11.1 percent for "organic" labelled samples.

On the other hand, the average daily intake of vegetables by Keralites is low in comparison to the recommended quantity by the Indian Council of Medical Research (*The Hindu*, Feb. 8, 2010). The availability of vegetables per capita per day in the state, including imports, is approximately 290 grammes, which is less than the WHO recommended rate of 400 grammes, excluding potatoes and starchy tubers. According to the WHO, not eating enough fruits and vegetables is the cause of 14 percent of gastrointestinal cancer deaths, 11 percent of ischaemic heart disease deaths, and nine percent of stroke deaths worldwide.

It is therefore of paramount importance to augment vegetable production in the state with a multi-faceted programme. Extension of vegetable cultivation to unutilized land, attracting more people to vegetable cultivation, group farming, promotion of kitchen gardens, etc. are important among them. However, all these programmes have their own limitations too. Shortage of cultivable land, heavy rain during a considerable portion of the year and many other techno economic constraints put a hurdle in increasing vegetable cultivation through conventional method of production. Moreover, different types of pest attacks and a variety of plant diseases also causes innumerable problems to farmers and hence prevent them from vegetable cultivation. At this juncture, high-tech farming in greenhouses has great relevance to increase production and it is gaining popularity around the world.

A greenhouse is a structure covered with transparent sheets that provides controlled conditions for growing vegetables and flowers. Transparent materials, such as glass or plastic, typically cover the greenhouse. The greenhouse covered by plastic sheets is termed a "polyhouse." Currently, nearly 90 percent of greenhouses use UV-stabilised polythene sheets as the glazing material (Nair & Barche, 2014). The terms "greenhouse" and "polyhouse" are used interchangeably from here on. The major advantages of it are that it requires less land and has a higher yield compared to open-field cultivation. Besides that, vegetable cultivation is possible in all weather conditions. Greenhouses are not a single type but contain a variety of forms. Some are attached to automated irrigation and fertiliser application methods, and some others are simple bamboo structures. Their initial costs, as well as their performance, are also different.

More than 50 countries in the world operate greenhouse cultivation commercially. China is a prominent country, having more than 2.5 million hectares of greenhouses. Israel grows most of the vegetables it needs in greenhouses, even though the weather and water supply are not good for growing vegetables.

The National Horticulture Mission (NHM) and many state governments give subsidies to encourage greenhouse cultivation. The first greenhouse in India was established in 1988. In the year 2000, there were more than 1000 hectares of greenhouses in the country. It increased to 5730 hectares by 2012. Maharashtra, Uttarakhand, Karnataka, and Jammu and Kashmir are the prominent states with greenhouse cultivation (Gautam & Kumar, 2016).

In Kerala, the concept of the greenhouse has become popular during the present decade. The Kerala government and Kerala Agricultural University have encouraged this type of cultivation in recent times. There were more than a thousand greenhouses with an average size of between 40 and 400 sq. m. in Kerala to produce salad cucumbers, capsicum, yardlong beans, ladies' fingers, tomatoes, etc. Generally, vegetable cultivation is not possible in the state throughout the year due to 4- to 5-month-long heavy rain.

As per the report published by the Department of Economics and Statistics in 2017, agriculture and allied activities' contribution to the state's gross value added is decreasing year after year; it was only 10.96 percent in 2015-16. Furthermore, agriculture in the state has stagnated and reported negative growth in the same year. As a result, agricultural production and productivity suffer.

Kerala, on the other hand, is the prominent state in India with the highest level of unemployment. The state's overall unemployment rate is 12.5 percent. Another peculiarity of the state's unemployment rate is that it rises as education and skill levels rise. The state's educated youth require more job opportunities, but they are hesitant to take on ordinary, laborious, back-breaking agricultural jobs.

Today, the need to secure our food supply and self-sufficiency is vital as the demand for fresh, healthy, and safe food is ever-increasing. Unlike open-field farms in most places, greenhouses can deliver local food continuously throughout the year, making them an ideal way to meet the needs of the local food market and overcome future challenges, including global food security (Netafim, 2020). Greenhouse cultivation appears to be a solution to three major problems in the state: a year-round vegetable shortage, a reliance on neighbouring states for vegetables, a significant portion of which is contaminated with chemical residue, and rising unemployment among educated youth. Greenhouse cultivation, on the one hand, transforms cultivation from a laborious to a lucrative activity, and on the other hand, it provides a remunerative return to the cultivator. Many young and educated people are attracted to greenhouse cultivation.

The cultivation system has both advantages and disadvantages. This system necessitates a high initial investment, technical know-how, and close attention to the plants. The main advantages are pest-free products, high-quality products, all-weather cultivation, and so on. However, its economic viability and feasibility are more important than any other consideration. The economic viability and feasibility of this system must be ensured in order to expand vegetable and fruit cultivation under it. In Kerala, such a thorough investigation is not noticed. As a result, there is a research gap in this area. This study is an exploratory examination of the economic characteristics of high-tech farming, with a focus on greenhouse vegetable farming in the state.

1.2 Statement of the Research Problem

Vegetables, being crucial food crops, are cultivated using various methods in Kerala. The state commonly employs traditional techniques in paddy fields and intercropping in coconut and banana plots for commercial vegetable cultivation. Additionally, the practice of growing vegetables in small plots within household backyards, known as kitchen gardens, is not uncommon, primarily for self-consumption. Furthermore, various clubs, social organizations, neighbourhood associations such as '*Kudumbasree*' units, and even schoolchildren actively participate in vegetable production in Kerala. However, these efforts are often seasonal in nature, and there is currently no year-round commercial vegetable production in open fields within the state.

Consequently, Kerala relies on neighbouring states to fulfil a significant portion of its vegetable requirements. Regrettably, many of the imported vegetables are found to be contaminated with chemical pesticides. Hence, there is a pressing need for Kerala to significantly enhance its vegetable production to meet its demands while ensuring safer and more sustainable practices.

In light of these circumstances, a new method of cultivation is gaining prominence worldwide: high-tech cultivation in covered greenhouses or polyhouses. This innovative approach effectively addresses three significant challenges in vegetable cultivation simultaneously. Firstly, it enables year-round production, regardless of weather conditions. Secondly, it reduces the need for chemical pesticides. Lastly, it offers employment opportunities to educated, unemployed youth, making it an appealing option. Notably, this system tends to deliver higher productivity and product quality in comparison to traditional methods.

Despite the initial high setup costs, the greenhouse farming system has garnered increased interest and adoption among farmers globally in recent years, particularly among young, educated farmers who recognize its numerous advantages.

Greenhouse crop production is now a growing practice throughout the world, with an estimated 405,000 ha spread all over the world. The greenhouse production, which emerged in northern Europe, spread into other areas of the world, including the Mediterranean, North America, Asia, and Africa, with various rates and degrees of success. Countries situated in the Mediterranean area have become competitive producers of greenhouse vegetables during the last 20 years (Wilfried et al., 2013). Major players in greenhouse cultivation in the world (area in hectors) are Japan 54000, Turkey 10000, China 48000, Holland 9600, Spain 25000, USA 4000, South Korea 21000, and Italy 18500 (Sanwal et al., 2004). One of the most successful ventures in the field of high-tech greenhouse farming is that of Israel. Despite a lack of arable land and groundwater, Israel has made remarkable progress in greenhouse vegetable cultivation (Mehl, 2017). A study in the Philippines shows that the crops grown under the structure are more productive in the cases of sweet pepper, tomato, and bitter gourd, while watermelon gained no advantage. A regression analysis shows investment in protected cropping structures for vegetables is economically feasible in the eastern Visayas, Philippines (Armenia et al., 2013).

From the 1980s on, experiments in greenhouse vegetable cultivation started in India. A project of four high-tech greenhouses helped to increase the farm's income up to Rs. 7 lakh per annum. Therefore, thousands of farmers in Haryana are shifting from traditional farming to protected cultivation (Warsi, 2017). The Centre of Excellence for Vegetables was established in 2011 in Haryana. It demonstrated vegetable cultivation under different structures, namely greenhouses, net houses, etc. (Saini, 2015). Due to stagnant paddy and wheat cultivation, some farmers have switched over to vegetable cultivation and floriculture. But most of their efforts failed due to uncertainty in yields. That is why the option of protected cultivation (PC) deserves serious consideration, especially in the context of the goal of doubling farmers' income by 2022, as envisaged by the Prime Minister (Sangwan, 2017). A study at the Indian Institute of Horticulture Research, Bangalore, during 2002–04 shows that the production of capsicum was profitable while tomatoes were not under greenhouses (Murthy S. et al., 2009).

Various attempts were made to promote greenhouse vegetable cultivation in the state of Kerala. As a result, many units were started all over the state recently. The one-cent greenhouse is one of the models initiated by Kerala Agricultural University (KAU). However, several units were closed within a few years as well (Manoj, 2015). Under the hi-tech agriculture scheme, the State Horticulture Mission (SHM), in collaboration with the National Horticulture Mission (NHM), offers up to a 75 percent subsidy for the construction of naturally ventilated tubular greenhouses (The Hindu, July 7, 2013). According to R. Ajith Kumar, Director of Agriculture, Kerala State, there are 1108 greenhouses of 40–400 sq. m. actively engaged in crop production in Kerala. Major vegetables being cultivated in greenhouses are salad cucumber, capsicum, yardlong bean, bindi (lady’s finger), tomato, etc. (Kumar, 2015). Technology assessment programmes on rain shelter cultivation of vegetables were initiated in three farmers’ fields at Koorachund, Thamarasseri, and Chakkittapara Panchayaths of Kozhikode district. The trial was a huge success, with farmers harvesting 20 to 30 percent more than in open cultivation (Pradeepkumar et al., 2015). According to a research report submitted to the State Planning Board, there are 617 greenhouses in various districts of the state, covering a total area of 336,134 sq. m. Of them, the prominent districts were Ernakulam, Wayanad, Thrissur, Thiruvananthapuram, and Palakkad. Greenhouses are present in all districts, even though Kasargode has the fewest (Radhika, 2016).

However, it is important to note that there has been a lack of sufficient economic studies conducted in Kerala to analyse the viability and feasibility of greenhouse farming. The greenhouse cultivation method is not widely adopted among the farmers in Kerala, although there has been a recent increase in its acceptance. Therefore, it is imperative to assess the extent of greenhouse cultivation in relation to the total vegetable cultivation in the state. This involves understanding the number of cultivators involved, the amount of land under greenhouse cultivation, and the quantity of vegetables produced within these greenhouses.

It is also worth considering the various methods of greenhouse cultivation, including organic and non-organic approaches, automatic and manual irrigation systems, small-scale and large-scale operations, and naturally ventilated versus fan-ventilated setups. Do these diverse methods all yield similar economic feasibility and viability, or do they differ significantly? Additionally, the choice of crops cultivated in greenhouses can vary, with salad cucumbers, capsicum, yardlong beans, and tomatoes being the predominant choices in Kerala. It is essential to investigate potential differences in the economic performance of cultivation for each of these cases.

Beyond economic considerations, greenhouse farming presents technical and economic constraints that need to be addressed. Understanding how greenhouses overcome these obstacles is a vital aspect of the study. Greenhouse farming is a complex endeavour that demands a high level of expertise and technical knowledge. Therefore, it is intriguing to examine the correlation between the socio-economic characteristics of farmers and the success or failure of their greenhouse units.

Another area of focus should be the impact of the scale of operation on the productivity and profitability of greenhouse farming. Analysing the strategies employed by operators to overcome the technological and economic challenges of greenhouse farming is also a key aspect of this research. In summary, this study aims to shed light on the economic, technical, and socio-economic aspects of greenhouse farming in Kerala, providing valuable insights for both policymakers and practitioners in the field.

1.3 Objectives of the Study

1. To find the extent of high-tech vegetable farming in Kerala and their role in the production of vegetables.

2. To analyse the socio-economic features of high-tech farmers and their influence on production and productivity.

3. To analyse the economic viability of vegetable farming inside the greenhouses.

4. To find techno-economic constraints of greenhouse vegetable farming.

1.4 Major Hypothesis of the Study

Hypothesis 1: The growth of high-tech cultivation of vegetables in greenhouses in Kerala was sustainable during the period between 2009-10 and 2019-20.

Hypothesis 2: All socio-economic category farmers have engaged in high-tech cultivation in greenhouses in Kerala, and the difference in their socio-economic status has a significant role in the production and productivity of their farms.

Hypothesis 3: The cultivation of vegetables in greenhouses in Kerala state was high-tech in all senses, as evidenced by the facilities used in farms.

Hypothesis 4: High-tech vegetable cultivation in greenhouses in Kerala was a profit-generating activity for the farmers.

Hypothesis 5: There were no significant technical and economic constraints for high-tech vegetable farming in greenhouses in the state of Kerala.

1.5 Research Methodology

This study is based on primary and secondary data. Secondary data was collected from district-level principal agricultural offices, journals, newspapers, official reports, and the Economic and Political Weekly (EPW) Research database. Secondary data was primarily used for conceptual clarity and problem formulation, as well as to determine the extent of vegetable cultivation and greenhouse vegetable cultivation in the state.

The population of this study was all the farmers cultivating vegetables in covered greenhouses in the state of Kerala. The sampling frame was prepared using a list of farmers who followed this farming method. Their lists were available at the district offices of the Department of Agriculture as all the farmers had received the subsidy. To find the extent of the contribution of greenhouses to total vegetable cultivation, the total area under greenhouses in square metres (sq. m) is estimated. The number of greenhouse cultivators in different years was found to be a good indicator of the level of acceptance of this method among farmers.

1.5.1 Sample: For primary data collection, the Slovin or Yamane formula n= N/(1+Ne^2) is used to determine sample size (Adam, 2020). N = 837 and e =.07 were used in this study. Accordingly, the sample size was determined to be 165, and they were divided among each district in proportion to the number and size of farms, as shown in Table 1.1. More weight was given to large and very large farms, while less weight was given to very small and small farms, comparing their proportion in the population. The primary data was collected through interactive personal interviews with farmers using a structured schedule. The value of the output of various vegetable crops per square meter is estimated and analysed to find which crop is more suitable for greenhouse cultivation.

Table 1.1
Sample Distribution- District wise

SL No	District	Size of Population	Size of Sample	Population Proportion	Sample Proportion
1	Thiruvananthapuram	89	17	10.63	10.30
2	Kollam	31	9	3.70	5.45
3	Pathanamthitta	27	5	3.23	3.03
4	Kottayam	47	9	5.62	5.45
5	Alappuzha	35	8	4.18	4.85
6	Ernakulam	97	17	11.59	10.30
7	Idukki	112	19	13.38	11.52
8	Thrissur	71	14	8.48	8.48
9	Palakkad	40	8	4.78	4.85
10	Malappuram	61	11	7.29	6.67
11	Kozhikode	48	9	5.73	5.45
12	Wayanad	107	20	12.78	12.12
13	Kannur	41	11	4.90	6.67
14	Kasargode	31	8	3.70	4.85
Total		837	165	100	100

Source: Secondary data collected from Principal Agricultural Offices

Table 1.2
Sample Distribution- Size wise

SL No	Size Category	Size of Population	Size of Sample	Population Proportion	Sample Proportion	Sample as % of population
1	Very Small (Up to 100 sq m)	171	19	20.43	11.52	11.1
2	Small (101 -300 sq m)	62	11	7.41	6.67	16.9
3	Medium (301-500 sq m)	441	89	52.69	53.94	20.18
4	Large (501-1000 sq m)	117	30	13.98	18.18	25.64
5	Very Large (Above1000 sq m)	46	16	5.50	9.70	34.78
Total		837	165	100	100	19.71

Source: Secondary data collected from Principal Agricultural Offices

1.5.2 Analytical Tools Used: As the data were not normally distributed, non-parametric tests such as χ2, Mann-Whitney U test, Kruskal-Wallis's test, Spearman's rho, and McNemar's test were mainly used along with descriptive statistics. A few regression models were also used for the analysis of the data.

To find the cost per unit of major crops cultivated under greenhouses, the cost estimation method C3 used by the Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers' Welfare, Govt. of India, was followed. The market price of the purchased or hired items was used. For own items, imputed values were used (*Concept—Cost of Cultivation and Production, 201*4–15). Due to the important role of government subsidy in greenhouse farming, not only private costs but also costs incurred by the government (subsidy) were taken into consideration. The entire cost of greenhouses can be divided into two categories: fixed and variable items. Land, greenhouse structure, mesh, pumps, fertigation system, water tank pH metre, and other monitoring devices were the major fixed-cost items. Labour, seeds and seedlings, fertilisers, pesticides, growing media, transportation, interest on working capital, etc. were the major variable cultivation costs (Seepersad et al., 2013). In the case of multi-crop greenhouses, for computing the cost share of each crop, the cost of joint inputs is divided in the following manner: (a) Implement repair and maintenance proportionate to crop time and the total use of this equipment. (b) Fixed capital cost (excluding land): in proportion to the time spent on each crop and the total use of this equipment. (c) manure, fertiliser, and pesticides in proportion to the standard area (square metres) under each crop in relation to the total area. (d) The rental value of land: in proportion to the standard area under each crop to the total cropped area (Velluva, 2017). Full supply prices for each crop were found, and it was stated which crop is more cost-effective for different-sized greenhouses, and different techniques were followed.

To find out the relationship between the scale of operation and output, Spearman's rank correlation was used. Crop-wise and method-wise differences were also found. Greenhouse farming is subject to both technical and economic constraints. The need for daily attention and irrigation, the attack of pests and diseases, the need for manual pollination, the lack of availability of quality seeds, manure, and fertilisers, the lack of storage facilities, the environmental threat of plastic covering materials, etc. were a few of the technical constraints. The heavy cost of initial investment, labour costs, a deficiency of proper marketing facilities, a lack of a sufficient price for the product, a lack of suitable crop insurance, etc. were the major economic constraints. The frequency distribution of various constraints was created. It helped identify important constraints in greenhouse farming. Cross-tabulation and $\chi 2$ tests were conducted to find out the association between the various constraints and methods of cultivation (organic and nonorganic), the scale of operation (large, medium, and small), the socio-economic condition of the farmers (education, gender, etc.), the nature of occupation (full-time or part-time), experience, technical knowledge, etc. For the data analysis work, MS Excel and IBM SPSS software were used.

Then, appropriate tables and diagrams were used to present the results derived from the data analysis.

1.6 Significance of the Study

The state of Kerala needs a huge quantity of quality vegetables every year. Resorting to neighbouring states forever is not a righteous policy, especially in the presence of high levels of pesticide residues in imported vegetables. Furthermore, due to excessive rainfall for half the year and the impossibility of relying solely on open fields, greenhouse farming in the state may be required to expand. Even though the initial cost of building a greenhouse is prohibitively expensive, many young farmers and vegetable growers enter the field. At this juncture, it is vital to assess how economically viable a greenhouse is. The conventional agricultural practice in the open field is not attractive to the young and educated people of Kerala, as it is drudgery in nature. Greenhouse cultivation, on the other hand, provides them with stable work as well as high-quality veggies throughout the year for the people of Kerala. As more farmers become interested in growing vegetables in greenhouses, it is important to figure out if the system is financially sustainable as a new way to farm.

1.7 Chapter Scheme

The presentation of this research study is divided into eight chapters. The second chapter, which follows this introductory chapter, goes over the important literature on high-tech vegetable farming. The literature studies are organised thematically, with sections on the current state of vegetable production, necessity, economic viability, and challenges of high-tech cultivation. The third chapter gives an overview of the high-tech farming strategy. The fourth chapter analyses the extent of high-tech vegetable cultivation in the state of Kerala using the data collected from Principal Agricultural Offices working in all the districts. The fifth chapter analyses the socio-economic characteristics of high-tech farmers and their influence on the production and productivity of various types of greenhouses. The sixth chapter deals with the economic viability of different greenhouses and crops using various statistical tools. Chapter seven consists of an analysis of various technical and economic constraints faced by the high-tech vegetable farmers in the state. The last chapter, chapter eight, gives a comprehensive description of the research findings from the various chapters. Furthermore, this chapter also covers some of the policy implications based on the research findings, implications for further research, and a conclusion.

1.8 Limitations

Greenhouses are usually used not only for vegetable cultivation but also for flowers, fruits, and raising seedlings. However, this study restricts its scope to vegetable cultivation only. There are large numbers of greenhouses all over the world, and India is not an exception. But the state of Kerala entered the field only recently. Therefore, the number of greenhouses in Kerala is limited. As per the report from the State Horticulture Mission (SHM), there were 890 GH farms in the state, but only 837 greenhouse farmers producing vegetables in the state were individually identified. Data collection from these farmers, widely scattered all over the state, was a herculean task. To overcome labour and cost constraints, a margin of error of 7 percent was used to determine the sample size. Moreover, as there was a large difference in farm size (ranging from 10 sq m to 4000 sq m), the parametric method for analysis was almost not applicable. Greenhouse vegetable farming in Kerala was not a single-crop farming activity. Farmers used to cultivate multiple crops under the same roof at a time. It created difficulties in estimating common costs separately for different crops.

CHAPTER II

REVIEW OF LITERATURE

2.1 Introduction

High-tech farming has been successfully practised in various countries around the world for decades. Many of these countries have been forced into this mode due to adverse weather conditions. In addition, shortages of agricultural land, water scarcity, and large-scale pest infestations have resulted in the loss of open-field cultivation or inadequate availability of produce.

In this chapter, a detailed review of related literature has been made to explore the need, importance, present scenario, features of farms, farmers, crops, productivity, and economic viability of greenhouse vegetable cultivation in the world, India, and Kerala. A wide variety of sources have been examined for this goal, including published articles, journals, books, websites, and research reports, including government-published reports. All of them shall be divided into theoretical and empirical reviews.

2.2 Theoretical Reviews

According to Prof. Gray, "agriculture economics may be defined as the science in which the principles and methods of economics are applied to the special conditions of the agricultural industry" (Gray LC, 1922). Hibbard defined agricultural economics as "a study of relationships arising from the wealth-getting and wealth-using activities of man in agriculture" (Hibbard BH, 1948). According to Jouzier, agricultural economics is that branch of agricultural science that treats the manner of regulating the relations of the different elements comprising the resources of the farmer, whether it be the relations to each other or to human beings, in order to secure the greatest degree of prosperity to the enterprise" (Jouzier, 1920). As a result, we might characterise agricultural economics as an applied discipline that is primarily interested in economic issues related to farmers' attempts to make a living. As we all know, their issues are vast and diverse in nature, but they may be divided into three categories: 1. production; 2. marketing; and 3. financing. As an applied science, agricultural economics plays a crucial role in developing the approaches, techniques, and procedures that may be used to address agricultural issues.

2.2.1 Production Function

The process of production involves using specific products and services to produce products and services of a different sort. It is the term used to describe the conversion of some inputs into a form that may be consumed. Input-output patterns and varied interactions between specific inputs and the products that go into producing the output are examples of these relationships. The levels of factor costs and product prices, as well as the characteristics of production patterns that enable the accomplishment of specifically targeted optimums, such as profit maximisation or cost reduction, are also taken into consideration (Robertson, 1971). The production function shall be expressed algebraically as:

$$Y = f(x1, x2, x3 \ldots\ldots xn)$$

Thus, a technical relationship between input and output is the production function. The production function, which shows the highest output from a specific input mix, remains static as long as technology does not change (Metcalf, 1969). It is a purely technical relationship that connects factor inputs and outputs. It describes the laws of proportions, that is, the transformation of factor inputs into products at any time period. It represents the technology of a firm, an industry, or the economy as a whole. The relationship between the factor inputs and outputs is wholly technical. It explains the laws of proportions, or how inputs from factors are converted into outputs at any given time. It stands for the technology of a business, an industry, or the entire economy (Koutsoyiannis A., 1979).

A homogeneous production function is one that can entirely factor k out of the equation if each input is multiplied by that number. The degree of homogeneity of the function is measured by the power v of K, which is also known as the returns of scale (Koutsoyiannis, 1979; Sadhu and Sing, 1988). The production function is regarded as non-homogeneous if it cannot be factored out. The Cobb-Douglas production function is a first-degree linear homogeneous production function. For the whole output of the manufacturing business, it considers only two input factors: labour and capita (Cobb and Douglas, 1929). Its functional form can be expressed as (Scitovsky, 1971).

$$Q = a\, L^{p}\, C^{1-p}$$

Where Q is output, L is the amount of labour, C is capital employed and a and p are positive constants where $p<1$.

Spillman made one of the earliest attempts to estimate a production function in agriculture. The empirical efforts by Spillman were published prior to the work by Cobb and Douglas in 1928, and the form of the production functions used by Spillman differed slightly. The Spillman function was

$$Y=M - AR^{x}$$

Where "Y" is the yield gained by applying "x" units of the growth factor in fertilisers, with the unit being any suitable quantity of the factor. "M" is the theoretical maximum yield achievable with any number of units of the growth factor, or the limit approached by Y as x increases forever. "A" represents the theoretical maximum increase in yield that may be obtained by raising x forever. "R" is the ratio of a diminishing geometric series, the terms of which are the corresponding yield increments caused by successive unit increases in x (Spillman, 1923).

A large number of studies have been done to empirically analyse the technical and economic viability of high-tech vegetable farming all over the world. However, most of these studies were done by agricultural scientists whose main focus was technical viability. Only limited studies were conducted purely from an economic point of view to assess the economic viability. Therefore, the main purpose of this chapter is to look at the economic need and possibility of high-tech vegetable farming in India, particularly in the state of Kerala.

2.2.2 High-tech Farming

High-tech farming is a broad term that refers to the application of a variety of innovative tools in farming (robotics, ICT, big data, earth observation, etc.). Innovative technologies can help farmers and farm managers improve their performance. It involves eyes and touches to monitor what is going on (meteo sensors, soil sensors, canopy sensors, product sensors; on-board or proximal sensors); a mind to elaborate on data and provide instructions (data acquisition, data analysis, layers/images, DSS); intelligent arms to do precise and timely activities (machinery, programming/automation, robotics); technology-oriented services (installation, maintenance, and repair); and education (training, demo farms, and sites). Adoption of innovative agri-technologies in small and family farms; novel solutions for early detection of pests and illnesses; and improved animal health and welfare are some of the specific goals (*High Tech Farming*, n.d.).

High-tech farming uses cutting-edge technologies to build controlled environments for growing crops in greenhouses or polyhouses. Several economic theories are relevant to this situation:

2.2.2.1 The Cost Benefit Analysis (CBA): Cost-benefit analysis is a methodical technique used in economics to assess the possible costs and advantages of a plan, a course of action, or any choice. It is a useful tool for making decisions as it aids in determining whether the advantages of taking a certain action exceed its disadvantages or vice versa. In CBA, the overall economic effectiveness and attractiveness of a suggested course of action are assessed by contrasting its positive and negative effects (Jiang & Marggraf, 2021). The expenses of installing high-tech solutions in greenhouses or polyhouses with the anticipated advantages are compared in this economic theory. It enables farmers and investors to make well-informed choices regarding the economic viability of implementing these technologies.

2.2.2.2 The Economies of Scale: The phenomenon of cost advantages that a business or producer experiences as its manufacturing output increases is referred to as economies of scale in economics. In other words, the average cost of generating each unit of output reduces as production scales up. This impact is frequently observed across a variety of businesses and can be brought on by things like spreading fixed costs over a higher output, effective resource use, and enhanced manufacturing techniques (Stigler, 1958). The economies of scale may be impacted by the size of high-tech greenhouse or polyhouse operations. Because the expense of infrastructure and technology may be distributed over a greater production area, larger operations may benefit from economies of scale, which may lower the average cost per unit of output.

2.2.2.3 Resource Efficiency Theory (RET): Birger Wernerfelt first proposed the resource efficiency theory, also known as the resource-based view (RBV), in 1984. It gained wide acceptance in strategic management after Jay Barney expanded it in 1991. Barney's work emphasised the VRIN criteria (valuable, rare, inimitable, and non-substitutable) for assessing resource potential for sustainable competitive advantage. It is a strategic management and economic idea that focuses on how a firm's distinct resources and talents can result in a competitive advantage and superior performance. It highlights the significance of utilising resources effectively and efficiently in order to attain long-term competitive positions in the market (Barney et al., 2021). The goal of high-tech farming is to utilise resources like water, fertiliser, and pesticides as efficiently as possible. By employing resources more effectively, the economic theory of resource efficiency seeks to reduce waste, boost productivity, lower input prices, and improve environmental sustainability.

2.2.2.4 Technology Adoption and Diffusion Theory: According to reports, Everett Rogers, an American communication expert, developed this theory. In 1962, he published his ground-breaking book "Diffusion of Innovations," in which he first presented this thesis. The technology adoption and diffusion theory is a social science theory that examines the adoption and diffusion of new technologies across populations and communities. It is extensively researched in the fields of marketing, sociology, and innovation management (Miller, 2015). Understanding how rapidly and widely high-tech agricultural practices are embraced in the greenhouse or polyhouse industry requires knowledge of economic theories relating to technology adoption and dissemination. The transmission of knowledge, training, and network effects are just a few of the factors that affect the adoption rate.

2.2.2.5 Theory of Asymmetric Information: An economic concept known as information asymmetry, or the notion of asymmetric information, deals with scenarios in which one side of a transaction has more or better information than the other. In these situations, it is claimed that one party has an "information advantage" over the other (Akerlof, 1970). Asymmetric information can cause market distortions and unfavourable results (Pressman, 2008). Large volumes of data are produced by high-tech farming via sensors, satellite photography, and other sources. The impact of information access on market behaviour is examined via the economic theory of information asymmetry. This theory can be used in agriculture to comprehend how decision-making and resource allocation are affected by having access to real-time data on crop health, soil moisture, weather conditions, and market prices.

2.2.2.6 Risk Management Theory: A methodical approach to recognising, evaluating, and managing risks in a variety of situations, such as business, finance, and project management, is known as risk management theory. The main objective of risk management is to increase opportunities for success while minimising the negative effects of uncertainty. This theory offers a well-organised framework for proactively and strategically addressing risks and uncertainties (Packham, 2019). Farmers can handle risks related to weather variations, market volatility, and other uncertainties with the aid of high-tech farming. Economic risk management theories emphasise techniques like diversification, insurance, and hedging measures, all of which can be improved by data-driven decision-making in precision agriculture.

2.2.2.7 Theory of Opportunity Cost: Early economic theorists like David Ricardo, Friedrich von Wieser, and Lionel Robbins laid the foundation for the idea of opportunity cost. Wieser focused on alternative costs, while Ricardo introduced comparative advantage. In order to emphasise the significance of choice in economic decision-making, Robbins defined economics as the study of human behaviour as a relationship between purposes and limited resources with alternative applications (Jensen, 1982). Adopting high-tech farming practices requires farmers to invest their time, money, and resources. Economic theory instructs us to take opportunity costs—the value of the next best alternative foregone—into account. It is important to compare the benefits of incorporating technology with other possible investments or activities farmers could have done with their resources.

2.2.2.8 Innovation Theory: Joseph Schumpeter popularized this hypothesis that examines the connections between technological advancement, innovation, and economic growth. It places a strong emphasis on how innovation can increase productivity and foster long-term prosperity. While causing the demise of antiquated technologies and practices, innovation also gives rise to new, more productive industries (Ziemnowicz, 2013). High-tech farming is typically associated with higher productivity because of improved resource management, data-driven decision-making, and optimised processes. The theory of innovation and productivity investigates how technological advancements can boost the economy and increase output in a variety of industries, including agriculture.

2.2.2.9 Theory of Human Capital: In the 1960s, economist Gary S. Becker developed the human capital theory, which includes human abilities, investment, and education in economic analyses. It implies that just as companies invest in physical capital, people may improve their economic ability by investing in their education and talents (Becker, 1964). This theory has had a substantial impact on economics, influencing policies regarding workforce development, education, and labour market results. For the operation and management of sophisticated equipment and technologies, high-tech agriculture needs skilled labour. When thinking about the abilities and knowledge required for the successful adoption of new technologies, human capital theory, which emphasises the value of education and training in boosting productivity, is pertinent.

2.2.2.10 Environmental Economics: The study of how economic practices and government regulations affect the environment is at the heart of the field of environmental economics. It aims to understand how economic decisions, market forces, and policy interventions affect the environment and natural resources, as well as how environmental concerns influence economic outcomes. Environmental economics seeks to address environmental issues while taking economic efficiency and sustainability into account by offering knowledge and tools (Tietenberg & Lewis, 2018). High-tech agriculture can have an impact on the environment, both positively and negatively (for example, by using fewer pesticides or using more energy). The trade-offs between economic expansion and environmental preservation can be evaluated using economic theories linked to environmental economics, such as externalities and sustainable development.

According to NABARD (2019), high-tech farming has many advantages, including increased yields by a factor of five to eight, high productivity per unit area, and a significant reduction in crucial inputs like water (by as much as fifty percent), fertilisers (by as much as twenty-five percent), and insecticides (by as much as twenty-five percent). And it works well in locations that are both flat and hilly, as well as in locations that are salty, waterlogged, sandy, or have a lot of other types of topographical variation. There are a wide variety of high-tech farming methods and traits. No-till farming, hydroponics, which is a method of growing plants that does not require the use of soil but instead relies on mineral fertiliser solutions in a water solvent, protected growth in a greenhouse with solar and photovoltaic systems, vertical farming (growing crops without soil or granular media), and aeroponics (growing plants in air or a mist environment) are both on the rise (*Hi-Tech Agriculture in India*, 2019).

According to Bhattacharyya et al. (2017), hi-tech horticulture is a modern, ecologically friendly, acceptable, and intensive technique that helps farmers increase their income by increasing their production and the quality of their products. It is a method for growing foods including fruits, flowers, vegetables, and spices that uses modern crop production methods and post-harvest management practices to ensure a seamless transition from seed or variety selection to final output. Now that high-tech horticulture has broken through the agro-climate barrier, consumers can buy vegetables and other horticultural commodities year-round, albeit at a premium.

Recently, horticulture has become not only a tool for diversification but also an integral part of food and nutrient security. The situation demands a change in modern crop production technologies. The necessity of the situation mainly emphasises the importance of vegetables in the diet, the limitation of open fields, and the presence of deadly pesticides contained in their products. It also includes a loss of income to farmers due to a cobweb movement in vegetable production and prices.

2.2.3 Role of Technology in Production Function

"High-tech farming" refers to the use of cutting-edge farming tools to increase yields and address other cultivation-related issues. The agricultural sector is generally subject to the rule of diminishing marginal returns. The advent of new inventions and technological developments, on the other hand, may allow for greater output to be achieved with the same investment of resources. Over the course of history, technology has progressed considerably. Enhancements include pest-resistant genetically modified seeds, stronger and more efficient fertilisers, and more advanced farming technology (Pindych et al., 2013). There are various forms of modern farming techniques, such as the application of high-yielding variety (HYV) seeds, the network of irrigation systems, farm mechanisation, chemical fertilisers and insecticides, protected farming systems, etc. An increase in overall productivity is the result of the technological advancement of all sectors.

Many economists use total factor productivity (TFP) to assess technological advancement, and it encourages economic growth, according to Carlaw and Lipsey (2003). The main issue mentioned by Hulten (2000) is that distinct TFP components are not measured explicitly but instead are grouped together as residuals. Within the TFP framework, they cannot be disaggregated.

2.2.4 The Cobb-Douglas production function

The Cobb-Douglas production function, first introduced by Knut Wicksell (1851–1926) and statistically tested to offer proof by Paul Douglas and Charles Cobb in 1928, is the most often used in economics to depict the relationship between output and inputs. A Cobb-Douglas production function that is linearly homogenous is given by:

$$Y= AK^{\alpha} L^{\beta}$$

Where Y = output, A = level of technology (constant), K= capital input, L = labour input, and α and β are constants determined by technology (Cobb and Douglas 1928)

The modified Cobb-Douglas production function that the study intends to use is expressed by

$$Y= A^{\lambda} K^{\alpha} L^{\beta} = F (A, K, L)$$

Where the returns to scale (ϒ) of the model are given by $\alpha+\beta+\lambda$

2.2.5 Embodied and Disembodied Technical Progress

Economic statisticians may attempt to divide technological progress into two components with a more in-depth examination. Embodied technical progress, which is improved technology due to new investments. New technological advancements are reflected in the equipment. Disembodied technical progress is an advancement in technology that results in increased output without the need for new equipment. Solow (1960) proposed a Cobb-Douglas-style technical advancement. He considered that all technological advancements are made possible by advances embodied in new physical equipment. He ruled out the notion of disembodied technical advancement and other sorts of technical progress. These two types of progress frequently complement each other. Disembodied technical advancement improves decision-making, resource allocation, and overall sustainability through data-driven insights and process optimisation, whereas embodied technical progress offers the required tools and infrastructure for farming operations. Both sorts of progress contribute to the advancement of high-tech vegetable farming, making it more efficient, productive, and ecologically friendly.

2.2.6 Farm Size and Productivity

The relationship between farm size and productivity is an area of dispute among agricultural economists. Agricultural economists disagree on the relationship between farm size and production. Indian agricultural data from the 1950s revealed numerous examples of asset allocation and utilisation on small and large farms, including an inverse link between farm size and annual production per hectare. Michael R. Carter investigated the link using data from a farm management survey conducted in Haryana during 1969–1970 and 1971–1972. For this objective, multistage stratified sampling approaches were adopted. According to the study's findings, the total analysis clearly supports an explanation of the inverse relationship in terms of the distinctive characteristics of small farm production (Carter, 1984).

Saini (1971) examined Sen's conclusions about the relationship between farm size and productivity, for example: (1) When family labour used in agribusiness is given an 'attributed value' in terms of the decision wage rate, much of Indian farming appears to be unremunerative. (2) The advantage of agribusiness increases with the size of the holding, with 'profitability' evaluated by the excess (or deficit) of produce over expenses, including the associated estimation of own labour. (3) Overall productivity per acre of land decreases with holding size (Sen 1964).

Rudra and Sen (1980) conducted an empirical study of the inverse relationship between farm size and productivity, which did not yield a consistent image. In some areas, even the inversely related pattern is not visible. It is especially visible on small farms. Confirmation occurs more frequently than rejection. However, the inverse link is caused by intensive farming on small farms with the assistance of family labour, which has low opportunity costs. The fundamental reason for the survival of the smaller peasants is the low cost of family labour. Typically, the inverse size-productivity relationship is used to argue against large-scale agriculture, such as capitalist or cooperative farming. However, farm size is a generic variable, and interpreting it as the only factor influencing labour utilisation is a mistake. Though smaller farms can use cheap family labour, large farms have a better ability to use non-labour resources.

In their analysis of West Bengal, Chattopadhyay and Sengupta (1998) discovered that the inverse link between farm size and productivity is more noticeable in agriculturally developed sections of the state than in less developed regions. They used farm-level disaggregated data obtained by the CSSCC in 1989–1990. The argument over the relationship between farm size and productivity, according to Fan and Chan-Kang (2005), has a long history. Small farms were seen to be more efficient in the 1960s due to advantages such as better utilisation of resources, particularly family labour, and close monitoring of production activities. However, following industrialization, a labour shortage for agricultural activities necessitated larger farms in the 1970s and 1980s.

2.3 Empirical Reviews

2.3.1 Vegetables: An Essential Element of Food

Vegetables are plant parts that can be eaten raw or cooked for human consumption. They provide most of the vitamins and minerals that humans require. Vegetables' value as part of a healthy diet has been the subject of several studies around the world. The study of Love and Sayed (2001) observed that substances in vegetables and fruits that may help to protect against disease are dithiolthiones, isothiocyanates, Indole-3-carbinol, allium compounds, isoflavones, flavonoids, protease inhibitors, saponins, phytosterols, inositol hexaphosphate, dietary fibre, vitamin C, vitamin E, folic acid, beta-carotene, lute, lycopene, selenium, D-limonene, and coumarins. It is now widely believed that a lack of vegetables and fruits, among other things, contributes to the development of every type of cancer in people. Male mortality from coronary heart disease (CHD) is strongly inversely associated with vegetable and fruit consumption. Malnutrition increases the likelihood of an infection and lengthens its treatment. The immune system is weakened by malnutrition, which both makes illnesses more likely and lengthens the time it takes to recover from them. Carotenoids, which are found in many vegetables and fruits, are precursors to vitamin A, which is essential for maintaining a healthy lymphocyte pool and participating in the T-cell-mediated response to infection. Cataract risk is enhanced in people who do not obtain the recommended daily quantity of vegetables and fruits

(3.5 servings). This finding highlights the necessity of including vegetables and fruits in one's diet to reduce the risk of disease.

The positive effects of eating fruits and vegetables were detailed in research by Duyn and Pivonka (2000). In order to maximise nutrition and, by extension, reduce illness risk and maintain good health, it is crucial to increase consumption of a variety of vegetables, such as green leafy, cruciferous, and deep yellow-orange kinds, and a variety of fruits, such as citrus and orange types. The risk of developing chronic diseases is inversely correlated with the frequency with which people consume fruits, vegetables, whole grains, and other plant foods (Liu, 2013). However, there is a sizable gap between what Americans eat and what the 2010 Dietary Guidelines for Americans recommend. The main goal is to get people to eat nine to thirteen servings of vegetables and fruits each day. The bioactive chemicals and other nutrients in whole foods work in harmony, or interaction, which is why eating plants like fruits, vegetables, and whole grains can improve your health. Therefore, for maximum nutrition, health, and well-being, consumers should get their nutrients, antioxidants, and bioactive compounds from a balanced diet, which includes a wide variety of fruits, vegetables, whole grains, and other plant foods.

According to the World Health Organisation, eating plenty of fruit and vegetables can help stave off serious conditions, including cardiovascular disease and some forms of cancer. Low fruit and vegetable consumption is responsible for about 16.0 million (1.0%) disability-adjusted life years and 1.7 million (2.8%) deaths worldwide. Inadequate consumption of fruit and vegetables is also linked to roughly 14 percent of gastrointestinal cancer fatalities, 11 percent of ischemic heart disease deaths, and 9 percent of stroke deaths worldwide. For the prevention of chronic diseases like heart disease, cancer, diabetes, and obesity, as well as the prevention and alleviation of several micronutrient deficiencies, a recent WHO/FAO report recommends a minimum of 400 grammes of fruit and vegetables per day, other than potatoes and other starchy tubers. In 2003, the World Health Organisation and the Food and Agriculture Organisation initiated a campaign to spread awareness about the health benefits of fruit and vegetables around the world. According to the National Institute of Nutrition (2011), malnutrition is largely a result of dietary inadequacy and unhealthy lifestyles. The deficiency of vitamins and minerals is the main cause of diseases related to the maintenance of the structure of the skin, bones, nerves, eyes, brain, blood, and mucous membrane. Vitamins are chemical compounds required by the body in small amounts, and minerals are inorganic elements found in body fluids and tissues; both must be obtained from a balanced diet. Vegetables and fruits are the major sources of vitamins and minerals. Therefore, a sufficient quantity of fruits and vegetables must be included in people's food baskets for healthy living.

KC KB et al. (2018) estimated both land usage and nutritionally advised diets by comparing the amount of food produced globally to what nutritional experts regard as a healthy diet. They consulted numerous food and agriculture data sources and followed various dietary guidelines and suggestions. Food availability per person per day exceeded the recommended 2200 kilocalories; however, a closer look at the data when food is broken down by category reveals a different picture. In terms of daily consumption, global agriculture provides 12 cups of grains, 5 cups of fruits and vegetables, 3 cups of oil and fat, 3 cups of protein, 1 cup of milk, and 4 cups of sugar. The Health Hazard Evaluation Programme (HHEP) recommends a diet with 8 servings of whole grains, 15 servings of fruits and vegetables, 1 serving of oil and fat, 5 servings of protein, 1 serving of milk, and no added sugar. According to the data, the globe is currently producing an abundance of grains, fats, and sugar while suffering from a severe shortage of vegetables, fruits, and even, to a lesser extent, protein. Starchy vegetables like potatoes are included in the vegetable category even though they are not considered vegetables by many nutritionists.

According to research by Mukhopadhyay and Thomassin (2012), increasing the quantity of vegetables and fruits Canadians eat can increase GDP and employment, whereas doing the opposite can have the opposite effect. Canada's employment and GDP might both increase because of the integrated strategy's focus on four types of food. The article suggests that an appropriate portfolio of fiscal policies is needed to provide households with incentives to adjust their food consumption behaviours towards a healthy diet.

After considering everything that has been said, it is concluded that vegetables are an indispensable component of meals, both in terms of preventing illness and ensuring that the body functions properly. However, the production practices of farmers are the primary factor that determines the supply of vegetables. The characteristics of vegetable cultivation as well as its scope are going to be dissected in the following paragraphs of this chapter.

2.3.2 Vegetable Production: Present Scenario

In 2017, the total global production of vegetables amounted to approximately 1094.34 million MT. The varied climate of India makes it possible for many kinds of fresh fruits and vegetables to be grown there. It is the second-largest producer of fruits and vegetables in the world, behind only China. Out of a total land area of 1,02,59,000 hectares, India produced 184.4 million metric tonnes of vegetables. The country had 10.1 million hectares dedicated to the cultivation of various vegetables. On the other hand, India's production of vegetables falls short of demand by about 30 percent.

The area of vegetable cultivation in Kerala in 2016–17 was 46732 ha (*Agricultural Statistics 2016–17*, 2017). Only 45 percent of the required vegetables are produced in the state. In other words, Kerala imports approximately 55 percent of its vegetable requirements from neighbouring states, resulting in annual expenditures of more than Rs. 1500 crore (Varma, 2016). By 2020, the state will require about 20 lakh metric tonnes of vegetables a year (*Directorate of Agriculture*, 2016).

The Kerala government provides one of the biggest cash subsidies for vegetable producers in India. The annual subsidy for vegetable producers is Rs. 25,000 per hectare, whereas the subsidy for cool-season vegetables is Rs. 30,000 per hectare. Farmers who grew bananas received a yearly subsidy of Rs. 30,000 per hectare. These subsidies cover all costs associated with farming, including seeds, planting materials, fertiliser, pesticides, and labour. Kerala's vegetable farmers are paid base prices (equivalent to MSPs) for 16 different crops after harvest. So far, no other Indian state has declared a base price for vegetables. If the price goes below the base price, the state government has agreed to buy the product at the base price (*Kerala Development Report 2021*).

In the literature survey, it was found that vegetables are essential for a healthy life, but the production of vegetables is less than the required amount in India as a whole and in Kerala in particular. However, vegetables can be produced using alternative methods. The following section discusses alternative methods of vegetable cultivation.

2.3.3 Methods of Vegetable Cultivation

At the dawn of civilization, people started growing vegetables for consumption. Most vegetables started out as untamed plants before people realised their value and began cultivating them near their residences. Later, with the help of science and technology, humans bred novel vegetable varieties and hybrid seeds to harvest record-breaking harvests. At first, individuals grew vegetables in the rich soil of their surrounding area. With time, humans developed new techniques for growing vegetables to keep up with the escalating need for food. Open-field soil cultivation is the standard practice; however, there are alternatives. In addition, urban farming has led to the development of container gardening in pots and polybags to make up for the scarcity of fertile soil. Worldwide, a lot of greenhouses and polyhouses are used for growing vegetables in a controlled environment.

2.3.4 Open Field Cultivation of Vegetables

Open-field cultivation is the conventional method of farming dating back to the start of cultivation. In this method, the farmer has to take care of the soil, sow seeds or transplant seedlings himself, apply manure, and protect the crop from hazards until harvest. It was the prevalent method before, but the risk of loss due to hard weather conditions is high. Besides that, fluctuations in the weather have become even more unpredictable recently. Therefore, the farmer has to be prepared with an appropriate reaction to the emerging problems. Cultivation of vegetables in all seasons is not possible. During the offseason, the production of vegetables will be low while the price of the products will be high. On the other hand, during the peak season, production will be high while the price is low. The result of the situation is an all-time low income for the farmers.

2.3.5 Hog cycle Phenomena in Vegetable Market

Based on observation of the vegetable market, a hog cycle phenomenon can be seen. "Hog cycles are cycles of over and underproduction of goods because of time lags in the production process. Such cycles often occur with agricultural products such as pork, where high prices in one year cause pig farmers to breed extra pigs, leading to oversupply and low prices in the following years" (*Collins Dictionary of Economics, 4th ed.,* 2005).

Each season, farmers are faced with a pair of simultaneous choices. At the outset, farmers decide how many acres to plant without knowing how much they will earn. Second, farmers decide how many acres to harvest based on the cost of commodities at the time of harvest. As the number of harvested acres is the primary factor in setting the current price, shipments are the primary indicator of market activity. The area planted is assumed to have a negative correlation with prices over time and a positive correlation with the preceding season (Wall & Tilley, 1979).

Kerala's vegetable market is a good example of this phenomenon. Vegetable output is often high in the peak season (summer) because of good climatic conditions, and the price is cheap as a result. However, because output drops drastically in the off-season (rainy season), prices rise. However, due to a decline in pricing during peak season and a decrease in productivity during the offseason, farmers receive only a modest income.

Changes in supply, caused primarily by weather conditions rather than changes in demand, are the primary reason for such price swings in vegetables. Vegetable growing is challenging because of the state's and neighbouring states' significant rainfall. High-tech greenhouse or polyhouse vegetable cultivation will help alleviate supply issues outside the traditional growing seasons. The farmers will also benefit from more consistent revenue throughout the year.

2.3.6 Pesticide Residue in Vegetables from Open Field

However, from a health perspective, vegetables are not safe to eat because they are highly contaminated with chemical residue. The report published by the Ministry of Health and Family Welfare for the period from April 2017 to March 2018 revealed the pathetic state of the safety of vegetables available in our country. Out of the total 12,821 vegetable samples collected from the various centres of the country and analysed to assess the presence of different groups of pesticide residues, no remains were found in 81.3 percent (10,422) of the samples. Pesticide residues were found in 18.7 percent (2,399) of samples and 1.9 percent (246) of samples that exceeded the FSSAI MRL. Furthermore, 13.3 percent of all samples analysed were contaminated by unauthorised pesticides. In the case of market samples, the figures were 79.4 percent, 20.6 percent, 14.8 percent, and 2.1 percent, respectively. The samples of brinjal showed the maximum number of pesticide residues, followed by tomatoes, okra, cabbage, cauliflower, cucumbers, etc. In farm gate samples, the figures were 84 percent, 16 percent, 11.3 percent, and 1.7 percent, respectively. However, in the case of organic badged samples, the reality is worse. The respective figures were 77.2 percent, 22.8 percent, 15.4 percent, and 1.6 percent (Status of Pesticide Residues in India, 2019).

Pesticide residue was found in 67 out of a total of 307 samples analysed (21.82 percent), as reported by the KAU Pesticide Residue and Analytical Laboratory in 2018. Samples taken from public markets had a pesticide residue rate of 20.7 percent, those from farmers' markets had a rate of 23.4 percent, those from private organic markets had a rate of 19.4 percent, and those from eco stores run by Krishibhavans had a rate of 12.5. All these numbers show how pervasive pesticide use is in the state's produce. In a report by Gopinathan S. (2018), out of the 497 samples taken for study by Dr Ambily of KAU, Vellayani, Thiruvananthapuram, 5.6 percent were found to have pesticide residue, and 11.2 percent of those labelled "organic" had chemical contamination from pesticides. In the case of open market samples, it was 7.6 percent, eco-shops 6.4 percent, and farmer-based samples 3.8 percent. This observation illustrates the extensive use of chemical pesticides in vegetables. Although the pesticide concentrations were much below the defined tolerances, continued ingestion of such vegetables, even with a minor degree of contamination, can accumulate in the body of the receptor and, in the long run, be dangerous to humans (Bhanti & Taneja, 2007). This problem should be tackled by the state. The need for the use of chemical pesticides in GH cultivation is extremely rare. A study conducted by Pradeepkumar, Bharadwaj, Roch C., and Geethu (2015) explained the potential of polyhouse systems for cucumber cultivation. Production of vegetables in Kerala is low during the monsoon period. Therefore, Kerala depends on neighbouring states for vegetables. If the farmers in the state were able to cultivate vegetables during the offseason, they could earn a better income. Protected cultivation under the GH made it possible.

2.3.7 Greenhouse Production of Vegetables: Concepts and Early Development

The growing of vegetables in greenhouses is the current fad in most developed countries. Hydroponics and aquaponics, two types of soilless farming, appeared later as well. Greenhouses (GHs) provide a safe haven for plants, allowing farmers to grow vegetables all through the year. This method appears to be more productive and profitable, too. Dalrymple (1973) defined greenhouses and provided a brief history of the invention. Plants can be grown in a semi-controlled environment inside this translucent structure. It's high enough to pass people and equipment through easily for routine farming tasks. Light, air temperature, and humidity may all be adjusted to create a custom environment. In this way, the plants are shielded from the elements. The system increases the annual capital and labour application per acre. When local field manufacturing is impractical, too expensive, or of low quality, this technique might be used to make the product. A few key aspects of this approach date back hundreds of years or more. For the duration of his reign (AD 14–37), the Roman emperor Tiberius Caesar made plans to ensure a steady supply of cucumbers. Pliny claims that during the winter months, movable beds were glazed with transparent stones and stored inside when the weather was unfavourable. Greenhouses as we know them now took shape in France and England between the late 1500s and the 1800s. Large-scale improvements were made to the layout and heating systems of vegetable-producing facilities beginning in the middle of the nineteenth century. Under GH conditions, lettuce was the first crop grown, followed by cucumbers and tomatoes. Carrots, celery, eggplant, peas, and string beans were the other main crops. Greenhouses today can be found in a wide range of shapes, sizes, covering materials, technological sophistication, aesthetic qualities, and financial returns.

Sabir & Singh (2013) took a look back at where protected farming stood in the world in 2013. Globally, GH covers roughly 623302 hectares; however, only 402981 hectares were used for vegetable production. China's 81,000 hectares of protected crop space are the largest in the world, followed by the United States' 70,400 hectares, South Korea's 47,00 hectares, and Japan's 36,00 hectares.

Only a few farmers practised greenhouse technology to produce vegetables in the state of Kerala. The state plan to promote high-tech cultivation was implemented from 2011–12 onward. However, the utilisation of funds for this purpose has begun to fall. Although it was 100 percent in 2012–13, it began to fall to 77 percent in 2013–14 and 71 percent in 2014–15 (*Report of Evaluation Study on Agro Service Centres in Kerala*, 2016).

2.3.8 Greenhouses for Vegetable Production: Physical Features

According to Dalrymple (1973), with the passage of time, GH technology saw advancements in construction techniques and materials. The acceptance and widespread usage of plastics as a covering was a fundamental transition in the post-World War II period. Plastic-coated GHs are currently widely used all over the world. In the last few years, commercial GH operations have started using a wide range of mechanical and electronic equipment.

Vegetable GH farming in the US was described by Greer & Diver (2000). They mostly consist of small, family-run farms with an area of 2500 to 10,000 square feet, along with a few larger farms with an area of 10 acres or more. According to Bucklin (2001), GHs differ greatly in terms of size and physical characteristics. Small houses under 3000 square feet and huge gutter-connected houses with a floor area of more than an acre are both included in its size range. Normal single-GH dimensions are 20–35 feet wide and 90–120 feet long. GHs are frequently used in gable and arched bays. The average size of farms in the first two regions was 380 sq. m, but it was 790 sq. m in Jamaica, according to a 2009 study by St. Martin et al. that examined the state of GH technology in Trinidad and Tobago and Jamaica. Glasses were formerly used as a glazing material, but in more recent years, synthetic sheets and films have taken their place.

According to Nair & Barche (2014), common types of greenhouses being used in India are: 1-plastic GH with natural ventilation; 2-GH with fan and pad cooling system; 3-Solar GH, 4-Walk-in Tunnels, 5-Plastic Low Tunnels, 6-Net Houses, Anti-Insect Cages, and 7-Underground Two types of GHs exist: those with natural ventilation and those with mechanical ventilation systems. Gable and sawtooth roofs both need ridge vents in order to allow for natural ventilation. The framework can be made up of either galvanised steel or wood. Steel frames are expensive but durable. Wooden frames are cheap to build, but they don't last long at all. Glass was formerly used for glazing, but in more recent times, synthetic sheets and films have taken its place. The material used for glazing must allow for the passage of light to the crop while minimising heat gain or loss (Bucklin, 2001). Naturally ventilated GHs are popular in the state, and various government schemes are specially designed to encourage them. Ventilated GHs are of two types: gable type and saw tooth. The sawtooth type is believed to be more suitable for the climatic conditions of the state. However, most of the farmers are not bothered by the difference (Kumar, 2018).

Suseela et al. (2018) studied the suitability of different shapes of polyhouses. For that, three naturally ventilated polyhouses with different shapes (namely gable, quonset, and mansard shapes) with the same floor area (150 m2), same eave and ridge height, and same roof and side ventilation were designed and constructed at HTR&TU, KAU, Vellanikkara, Thrissur; FSRS, Sadananthapuram; and RARS, Ambalawayal, in order to select the most suitable design of the polyhouse for the cultivation of salad cucumbers. The temperature and relative humidity within the polyhouses were monitored for the study. The temperature inside the gable-shaped greenhouse was 1.5 to 2°C lower than the other two greenhouses during the day's peak hours (12 p.m. to 2.30 p.m.). The relative humidity inside a gable-shaped polyhouse was found to be lower at night and higher during the day.

However, another study by Suseela (2018) revealed that the CO_2 content inside the structures did not differ significantly. Six types of Chilli were cultivated in all three polyhouses and open fields to choose high-producing Chilli cultivars for the humid tropical climate under the polyhouse. Statistical examination of the yield data revealed that all types of chillies were produced most efficiently in a gable-shaped structure, with the highest output for the Sierra variety (4.36 kg) within the gable-shaped greenhouse and the lowest yield for the Ujwala variety in the open field (0.221 kg).

2.3.9 Greenhouse Vegetable Crops

The selection of crops to be cultivated in GHs depends on many factors. Climate, the nature of demand for the product, potential yield, and revenue are prominent among them. Tomatoes are the leading greenhouse vegetable crop, followed by cucumbers, lettuce, and bell peppers in the USA (Greer & Diver, 2000). Sweet pepper and tomato were the major crops in Trinidad and Tobago and Jamaica (St. Martin et al., 2009). Sugarcane, sweet potato, green beans, carrots, and cucumber were the most common crops grown in Nigeria under GHs (Mijinyawa & Osiade, 2011). Cucumbers, tomatoes, peppers, bedding plants, cut flowers, and tree seedlings were the major GH crops in Canada (Laate, E.A., 2013). Leafy vegetables such as cabbage, cauliflower, brinjal, beans, peas, and coriander can be grown at high altitudes using the GH system (Kumar, Tyagi, & Kumar, 2017). The coloured bell pepper was the most common crop in the Caribbean region, accounting for 70.6 percent of GHs, followed by tomatoes (34.5%) and lettuce (8.8%) (Moulton A.A., 2017). Tomatoes, capsicum, cucumber, Chilli, and brinjal were the major crops under protected structures in Garunda, Karnal (Saini, 2015).

Salad cucumbers and yardlong beans are the prominent crops cultivated in Kerala under polyhouses because of their self-pollinating nature. Besides them, spinach and bitter gourds are also cultivated in the state (Kumar, 2018).

2.3.10 Greenhouse Vegetable Farmers

The entry of a person into an occupational activity depends upon many factors, such as tradition, skills, interest, and return. Cultivation is primarily a traditional activity in which many skills and knowledge are transferred from one generation to another. However, the high-tech cultivation under greenhouses requires special skills and knowledge, and most of them are not transferred from the old generation. Various studies reveal that education has a positive effect on agricultural productivity. Education and training can help farmers increase their mental ability to have a positive attitude towards the adoption of innovations in agriculture. The assimilation of new information and skills for agricultural activities is possible through education. Results from studies conducted in developing countries show that men and women do not adopt new technologies at the same rate. Therefore, the benefit will not be equal to their introduction (Sulo et al., 2012). The socio-economic characteristics of the greenhouse cultivators have to be analysed.

A study done by St. Martin et al. (2009) revealed that 63 percent of GH farmers possessed a secondary level of education in Trinidad and Tobago, while 64 percent of farmers in Jamaica possessed a college or university level of education. Male farmers made up 88 percent of those in the first two regions and 92 percent of those in Jamaica. 75 percent of farmers in the first two regions and 50 percent of farmers in the third region received no training in GH cultivation. Laate, E.A. (2013), analysed the costs and returns data for the various greenhouse crops produced across Alberta, Canada. There were about 328 GH operations in this region and around 1600 full-time and 3200 part-time workers. 99 percent of the GH area in this region is under commercial cultivation, and the remaining is confined to universities, colleges, and research stations. The study by Moulton A.A. (2017) found that in the Caribbean region, 80.7 percent of GHs were operated by individual farmers, and most of them (82%) were male. Although 72 percent of the GHs were larger than 6,000 square feet (sq. ft.), their contribution to the total production area was only 30 percent.

However, the socio-economic characteristics of GH farmers are less explored, especially in Kerala. Further research is required to analyse the same.

2.3.11 Cost of Greenhouse Vegetable Cultivation

It is important to investigate whether GH's output justifies the increased capital expense. According to estimates based on production in the USA and Canada, fixed costs account for roughly a third of the overall production cost. About one-third of the total cost and half of the operating cost went towards paying employees. There is a higher marginal cost associated with greenhouse production compared to open-field cultivation of the same crop over the same time period and same area (Dalrymple, 1973). There are typically two categories of expenses associated with growing vegetables using GH: building expenses and operational expenses.

According to Greer & Diver (2000), a commercial GH with a size of 30 ft. by 100 ft. and complete heating, cooling, and ventilation systems will cost between $10,000 and $30,000 to construct and equip. A low-cost GH of the same size can be constructed for as little as $500 to $1,500. Besides the initial construction cost, labour and energy are the two largest greenhouse expenses. Laate, E.A. (2013), analysed the costs and returns data for the various greenhouse crops produced across Alberta, Canada. The average investment cost per square metre varied from $118.37 for cucumbers to $300.51 for bedding plants. Total production costs varied from $94.54 per square metre for tomatoes to $125.83 for bedding and ornamental plants. Seepersad G., Ardon Iton, Compton Paul, and Janet Lawrence (2013) analysed the financial aspects of the GH vegetable production system in Jamaica and Trinidad and Tobago. According to them, the cost of production of tomatoes under the GH system was approximately three times higher than that of open-field cultivation. In the case of sweet pepper, it was up to five times. This is mainly due to the high cost of GH structures and the different inputs used in production. An article written by Diab, Magdi, Mousa, and Hassan (2016) analysed the GH experiment of cucumber cultivation in Aswan, Egypt. The construction of GH with a size of 4200 sq. m. incurred an initial cost of 126000 L.E., annual maintenance of 18600 L.E., a variable cost of 29617 L.E., and a fixed cost of 52170 L.E.

Murthy, Prabhakar, Hebbar, Srinivas, & Prabhakar (2009) analysed the economic feasibility of vegetable production under poly houses as a case study of two major crops, such as capsicum and tomato, and its economic feasibility in a naturally ventilated poly house at the Indian Institute of Horticultural Research, Bangalore, during 2002–2004. They generated data using the cost accounting method from 2001 to 2004. It was found that Rs. 2,36,000 was required as a non-land capital investment for a 500 sq. m. poly house. Rs. 10,340 was incurred as the average annual variable cost. The average cost of cultivation for tomatoes was Rs. 12,494, and the same for capsicum was Rs. 16,334. Singh (2017) compared the cultivation of vegetables under open and protected conditions in the Solan district of Himachal Pradesh. A representative sample of 100 farmers, containing 50 each of open and protected farmers, was selected from the Kandaghat and Solan blocks of the district. In this study, it was found that the cost of production of tomatoes and capsicum varied from Rs. 124380 to Rs. 140662 for tomatoes and Rs. 113878 to Rs. 118695 for capsicum. In the protected system, it was Rs. 23379 to Rs. 41248 for tomatoes and Rs. 23570 to Rs. 40393 for capsicum in 250 sq. m. to 500 sq. m. poly houses, respectively.

Bharti, Kumar, and Vibhuti (2017) analysed the economics of the protected cultivation of bell peppers in response to different plant growth regulators (PGR) under south Gujarat conditions. The cost of cultivation varied between Rs. 152869 and Rs. 155092, which is dependent on the cost of PGR and the packing cost of produce.

Senthilkumar, Ashok, Chinnadurai, & Ramanathan (2018) examined the economic and financial feasibility of polyhouse cultivation of capsicum in the Krishnagiri district of Tamil Nadu. In such a way, 120 farmers were selected randomly from the four blocks. For the study of the protected cultivation of capsicum, 30 sample farmers were selected. Costs are classified into A1, B1, B2, C1, and C2. A1 costs included machine labour, seedlings, farmyard manures, inorganic fertiliser, plant protection chemicals, miscellaneous costs, interest on working capital at 7 percent, depreciation on fixed capital, and land revenue. Cost B1 included A1 plus 12 percent interest on owned capital (excluding land), B2 included B1 and the imputed value of family labour, C1 included B1 plus the imputed value of family labour, and C2 included B2 plus the imputed value of family labour.

There may be a higher return from GH farming, according to a report by the National Committee on Plasticulture Applications in Horticulture (n.d.). They analysed a model project that was implemented in Shanthanahally village, Tiptur Taluk, Karnataka. The construction cost for 200 sq. m. of greenhouses was Rs. 1,47,000. The total operational cost incurred was Rs. 41,500, and the gross receipt was Rs. 81,275.

Kumar (2018) estimated the cost of vegetable farming in Kerala in 2016 for a polyhouse with a size of 10 cents. Incurred costs are seeds at Rs. 6000, fertilisers at Rs. 5500, periodic maintenance costs at Rs. 5000, transportation to markets at Rs. 7500, imputed labour costs at Rs. 40000, total variable costs at Rs. 64000, interest on working capital at Rs. 5760 (9%), the rental value of land at Rs. 2500, interest on fixed capital at Rs. 225, and depreciation (biannual depreciation for the structure) at Rs. 32000. The total cost incurred was Rs. 104485. He has divided the total cost into variable costs (Rs. 69,760) and fixed costs (Rs. 34,225) (Kumar, 2018). However, more research needs to be done to figure out how much the GH method of growing vegetables in the state costs.

2.3.12 Productivity in Greenhouse Vegetable Cultivation

In any type of production activity, one of the thrust areas of discussion is productivity. Various studies have been done worldwide to explore the productivity of GH vegetable cultivation. According to US experience, GH production of tomatoes was 20 to 30 lbs. per plant, and 2 dozen fruits per plant from cucumbers. In the case of peppers, the yield was 2.5 to 3 lbs. per sq. ft. The net income from conventional GH tomatoes ranged from $3,100 to $ 18,500 per GH unit if good yield and favourable market conditions prevailed. The greenhouse system for the production of vegetables can be done in two modes: organic and inorganic. They each have their own benefits and drawbacks. A brief discussion of that is necessary. GH production of vegetables can be done using the organic method or the nonorganic method. By citing the United States Department of Agriculture (USDA), the authors defined organic farming as a system that excludes the use of synthetic fertilisers, pesticides, and growth regulators. Organic farmers use the strategies of crop rotation, crop residue, animal manures, legumes, green manures, organic wastes, and mineral-bearing rocks to supply plant nutrients. Insects, weeds, and pests are controlled by mechanical and biological methods. Organic GH vegetable production has the potential to capture the market for out-of-season produce and is a sustainable method of production (Greer & Diver, 2000).

Muthiah (2001) compared the results of growing tomatoes in five different environments. Four of these five were contained within greenhouses or polyhouses, while the fifth was out in the open. T1 was completely covered with a UV film sheet (the doors on both sides were left open during the day to allow for ventilation), T2 had its entire roof covered with a UV film sheet and its four sides covered with 25 percent shade net, T3 had its four sides covered with 25 percent shade net and its triangular structured roof on both sides covered with UV film sheet, and T4 had its entire roof covered with a UV film sheet and half of its four sides covered with UV film sheet from the middle out. Plant height (75.40-108.57), node number (24.30-27.47), internode length (3.09-3.99), flowers per plant (75.67-218.13), average fruit weight (57.70-86.51), yield per plant (981.02-2145.21), and plant dry matter production (981.02-2145.21) all showed large seasonal variation in their mean values during the first season. The open field conditions resulted in poor growth and yield. T3 produced the highest fruit yields in the second season, at 2310.06 g/plant, ahead of T2 (2156.22 g/plant). From this, we infer that covering the poly greenhouse's parallelogram roof with UV-stabilised plastic film and using a 25 percent shade net on the four sides and triangle roof parts would boost the crop's output.

From December 2007 to April 2008, Parvej et al. (2010) conducted an experiment in a covered polyhouse and an open field in the Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural University. It was for the comparison of the phenological development and production potential of two varieties of tomato in these two different situations. The collected data on different parameters were compiled and analysed with the help of the computer package MSTAT-C. The least significant difference, or Duncan's New Multiple Range Test, evaluated the mean difference. The results of the test revealed that the number of fruits per plant, fruit length, diameter, and individual fruit weight, as well as fruit weight per plant, of tomato crops grown under the polyhouse were significantly higher than those grown in the open field. Individual fruits obtained from the polyhouse were approximately 10 percent larger, and the yield was 29 percent higher than those obtained from open-field plants.

Sabir & Singh (2013) reviewed the current status of protected cultivation in the global arena. The cultivation of high-value vegetables and cut flowers had great potential during the last decade. In the production of tomatoes, the USA had the highest productivity of 484 metric tonnes per hectare, followed by Canada (463 metric tonnes) and the Netherlands (460 metric tonnes). In the production of capsicum, the Netherlands had the highest productivity with 262 metric tonnes, followed by Canada (258 metric tonnes) and the United Kingdom (248 metric tonnes). The USA topped the world in the productivity of cucumbers with 690 metric tonnes, followed by Canada (530 metric tonnes) and the UK (480 metric tonnes).

Pahlavan, Omid, and Akram (2012) investigated input and output relationships in GH basil production in Esfahan province, Iran. The relationship between the energy input and yield was estimated using the Cobb-Douglas function. Basil yield was assumed to be a function of human labour, chemical fertilisers, farmyard manure, electricity, plastic covering, and transportation energy. The test revealed a model:

$$\ln Yi = \alpha 1 \ln X1 + \alpha 2 \ln X2 + \alpha 3 \ln X3 + \alpha 4 \ln X4 + \alpha 5 \ln X5 + \alpha 6 \ln X6 + \alpha 7 \ln X7 + ei$$

The coefficients were: human labour (α1) 0.47 (t=4.04 & MPP= 8.01), Chemical fertilizers (α 2) 0.08 (t=1.21 &MPP=0.15), Farmyard Manure (α 3) 0.02 (t=0.75 &MPP=0.18), Chemicals (α 4) -0.01 (t= -0.59 & MPP-11.11), Transportation (α 5) 0.12 (t=1.95 &MPP =0.50), Electricity (α 6) 0.06 (t=1.05& MPP= 0.01 7) and Plastic covering (α 7) 0.41 (t=3.55*&MPP= 0.48). The other important values of the model were DW 2.05 and R^2 0.99. Furthermore, sensitivity analysis revealed returns to a scale of 1.15.

Frangu, Popp, Thomsen, & Musliu (2018) analysed the major determinants of the input efficiency of Kosovar farmers in vegetable production. They studied the input efficiency of tomatoes and peppers on farms in Kosovo. The results of the analysis revealed input efficiency among GH tomato and pepper farms. For both types, farm yield was measured in kg, and input measures differed depending on the production specificities. Inputs for both crops included inputs such as insecticides, labour, greenhouse area in sq. m., organic fertilisers, and inorganic fertilisers of different stages. The study explored the inefficient input use in the production of GH tomatoes and peppers, which is caused by two factors. (1) excessive input consumption with no increase in yields; and (2) unfavourable market conditions, which caused wholesalers to offer low prices due to import pressure.

Pandiri (2018) studied the scope of polyhouse farming in Telangana State. The majority of the population of India lives in villages. Consequently, village and rural industries play a vital role in the national economy. Hard climatic conditions are the major challenge faced by farmers while producing food for the growing population. The growth of industries and urbanisation reduced arable land. Technological innovations like polyhouses have reduced input costs on the one hand and made cultivation possible throughout the year on the other. It helped the farmers fetch a higher profit. This method of cultivation requires less water and other inputs, although its initial cost is high.

According to an article by Sanwal, Patel, and Yadav (2004), the GH method is highly productive. For example, tomato production under GH is 4-fold more productive than open-field cultivation. Similarly, Sharan, Jethava, and Shamante (2005) investigated a facility for controlled-environment agriculture at Kothara, Kutch. This area was a hot and extremely arid region. The authors compared the yield of the GH system with that of the control beds. The GH had facilities to maintain the temperature at 36 degrees inside the house. Tomato yield was 2.7 times higher in this system than in open fields, and water usage was 34 percent lower. The capsicum in GH continued to fruit for nine months, while the same in the control bed lasted only five months. The yield of capsicum was 16 metric tonnes per hectare, which was 1.4 times higher than that of the control bed outside. The proportion of healthy fruits in the GHs was 90 percent, while it was only 60 percent in the control bed. Moreover, Mangal, Bhattacharya, Sudan, and Aswathi (2015) explored that in India, open field tomato cultivation yield on average was 180.6 quintals per hectare in 2013–14. It multiplied by five to ten times under protected cultivation.

Yadav et al. (2014) analysed the economic performance of low-cost polyhouse technologies during the winter season under northern Indian conditions. An experiment was conducted at the farm division of vegetable science, IARI, New Delhi. The result of the experiment can be summarised as follows: The cultivation of high-value off-season vegetables was found to be a viable activity for growing vegetables successfully during the winter with temporary protection from November to February. The product was off-season, which helped it fetch higher prices in the market. Under a structure of 50 sq. m., a total of Rs. 9500 was earned in the first year and approximately Rs. 24,000 from the second year onwards by raising off-season nursery seedlings. A net profit of Rs. 15, 000 and 59,500 could be earned by growing French beans and gherkins in the first year from a 1000 sq. m. area. From the second year onwards, it was Rs. 43,500 and Rs. 59,000, respectively. Thus, to enhance income and ensure the nutritional security of small and marginal farmers, off-season nurseries as well as vegetable cultivation under low-cost polyhouses were found to be useful. Moreover, this activity was found to be economical and profitable.

Saini (2015) stated that a centre of excellence for vegetables was established in Gharunda (Karnal) under the Indo-Israel work plan. Under protected structures, the centre demonstrated the cultivation of a variety of vegetables such as tomatoes, capsicum, cucumbers, chiles, and brinjal. The centre acquired a productivity of 302 metric tonnes (MT) of tomatoes, 211 MT of capsicums, and 151 MT of cucumbers per hectare. The success of this experiment caused an increase in protected cultivation from 42.5 hectares in 2010–11 to 63.46 hectares in 2011–12, 217.71 hectares in 2012–13, and 398.01 hectares in 2013–14 in the state. It was aimed at increasing protected cultivation to cover 2,500 hectares by the next five years. A presentation by Naik (n.d.) gave an account of vegetable production technologies in the organic method. According to him, protected structures yielded the best-quality vegetables. The approximate yield of different crops under this system was tomato 300 MT, capsicum 200 MT/ha/year, cucumber 73.2 MT/ha/75 days, and muskmelon 60 MT/ha/100 days.

Bharti, Kumar, & Vibhuti (2017) analysed the economics of the protected cultivation of bell pepper in response to different Plant Growth Regulators (PGR) under south Gujarat conditions. A significant increase in yield was noticed under polyhouse cultivation with the application of naphthaleneacetic acid (20 ppm).

Kumar et al. (2018) found that farmers could increase their crop yields by 150–300 percent by growing grafted seedlings of tomato, chilli, and capsicum in a protected environment and using better production methods like staking, mulching, inline drip fertigation, and IPM measures (pheromone lures and sticky traps). Furthermore, pesticide use is reduced by 70 percent in protected horticulture farming.

Nimbrayan et al. (2018) listed the major advantages of high-tech farming. Intensive use of resources such as soil, water, fertilisers, and energy is the major advantage of GH cultivation of vegetables. Productivity per unit of land, water, energy, and labour is higher under this method in comparison with open field cultivation. Moreover, round-the-year production and employment for farmers are possible with this method. This method reduces reliance on rainfall and maximises the use of land and water resources. In polyhouse farming, the farmer can harvest the crops approximately two to three times more without much damage or loss. Furthermore, by growing multiple crops that fetch higher prices due to the off-season nature of the vegetables, this method allows farmers to earn an income throughout the year.

A study conducted by Pradeepkumar, Bharadwaj, Roch, and Geethu (2015) in Koorachundu, Thamarassery, and Chakkittapara Panchayats of Kozhikode district explained the potential of the polyhouse system. Vegetables such as okra, tomatoes, brinjal, Chilli, spinach, cucumber, etc. were cultivated. Farmers harvested 25 to 30 percent more yield than in open-field cultivation as a result of the trial. A study for NABARD by Jasper (2015) revealed that the Hi-Tech method enabled raising the vegetable yield 10 to 12 times higher than that of open field cultivation. This technology is ideally suitable for vegetables and fruits because year-round production is possible under this method. Various studies in India revealed that the average yield of capsicum, cucumber, and tomato under GH was 1060 kg, 1460 kg, and 1530 kg, respectively, per 100 sq. m.

Sam and Regeena (2015) conducted a comparison study of the yield from naturally ventilated polyhouses and the open field. In the case of cool-season vegetables such as cabbage and cauliflower at the Farming System Research Station (FSRS) in Sadanandapuram, Kottarakkara, Kerala, the highest yield was reported in a polyhouse system compared to an open field system. The total yield of cabbage/cent was 151.64 kg in the polyhouse structure, while it was only 76.08 kg in the open field. The polyhouse system produced 99.32 percent more cabbage than the open field system. The yield of cauliflower was far higher. The total yield of cauliflower/cent was 121.25 kg in the polyhouse structure, while it was 46 kg in the open field. In other words, the polyhouse yield was 163.58 percent higher than the open field yield. No pests or diseases affected polyhouse cabbage and cauliflower. However, the attack of grasshoppers, caterpillars, and snails was high in the open field. Moreover, Sam and Regeena (2016) conducted two experiments in FSRS to assess the performance of the yield of trailing tomatoes and capsicum. The first was the comparison of the yields of these two crops under the polyhouse and in the open field. Gable-type polyhouse structures with an area of 96 sq. m. and natural ventilation have been constructed. A drip system with a fertigation facility and fogger units was also installed. The yield of these two crops increased in polyhouses by 82.84 percent and 90.85 percent, respectively, compared to the open field. The second experiment was the comparison of the same crops planted in grow bags under the poly house and in an open field with similar treatments for controlling bacterial wilt. The yield increase for these two crops was 300 percent and 321 percent, respectively. The higher production under polyhouses was the result of certain favourable conditions under polyhouses, such as lower solar radiation and lower humidity. The height of plants and the number of branches and leaves were higher in the crops grown under polyhouses as compared to open fields.

Vegetable production in the protected conditions of greenhouses is perhaps the most intensive agricultural production system under conventional and organic conditions. The cultivation of vegetables within the controlled environment of greenhouses is a highly concentrated kind of agricultural production, both within conventional and organic farming systems. The primary goals of organic greenhouse production align with those of conventional greenhouse production and farming practices, namely the replacement of harmful synthetic inputs with approved organic alternatives. However, the consequences of unbalanced production conditions cannot be avoided (Tittarelli, 2020). According to the 2014 Census of Organic Farming published by the US Department of Agriculture, organic vegetable production under the Controlled Environment Agriculture (CEA) framework, such as GHs, is growing. There are many different production processes under CEA, such as aquaponics, hydroponics, etc. Crops are grown directly in the soil in high tunnels, and fertility can be maintained with commercially available composts, cover crops, and organic fertilizers. As these products are advertised as valuable, they can be sold in local markets and/or marketed as certified organic products. As development in urban areas increases, there will be more interest in growing organic vegetables traditionally, with intensive production in small spaces such as vertical walls and passive solar heating structures. Farmers also make custom media mixes that require locally available materials (Rogers, 2017).

The DJM polyhouse of Mr Cicil Chandran from Neyyattinkara, Thiruvananthapuram, is also one of only two farms in the state to use the Centre for Development and Advanced Computing's smart farm module (CDAC). Humidity, water and air movement, soil, and carbon dioxide are all monitored by the smart farm module. It considers all of these aspects and makes the required adjustments to the settings, sending an SMS to notify the user of the changes. Everything about it is fully automated. This is backed up by the fact that in just three months of farming in a 600-square-metre field, he produced an incredible eight-and-a-half tonnes of vegetables (Hari, 2014).

However, studies to analyse the productivity of various GH vegetable crops in Kerala have not been noticed, especially in the case of GH commercial cultivation.

Therefore, there is a need for an analysis of the production and productivity of vegetable crops cultivated in commercial GHs.

2.3.13 Economic Viability and Feasibility of Greenhouse Vegetable Cultivation

Whether a production project is economically viable and feasible is an important criterion for deciding on investment in a commercial project. The cultivation of vegetables in GHs is a commercial activity. Therefore, it is very necessary to analyse its economic viability and feasibility. Traditionally, various techniques such as Net Present Value (NPV), Payback period, Benefit-Cost Ratio (BCR), and IRR are used by different authors for analysing economic viability and feasibility. These are defined as follows:

"Payback period calculations involve measuring the cash flows associated with a project and indicate how long it takes for an investment to generate sufficient cash to recover in full its original capital outlay" (Collins Dictionary of Business, 3rd ed. 2002, 2005).

NPV is "the discounted value of an investment's cash inflows minus the discounted value of its cash outflows. To be adequately profitable, an investment should have a net present value greater than zero" (*Wall Street Words*, 2003).

BCR is "a ratio representing the benefits of a project or investment compared to its cost. The BCR may be a strictly financial ratio, comparing the expected return to the cost of investment, or it may account for approximations of qualitative measurements" (*Farlex Financial Dictionary*, 2009).

IRR is "the discount rate at which the cash inflow equals the cash outflow. That is, the internal rate of return is the return necessary for the present value of an investment to equal what one spends in making the investment" (Financial Glossary, 2011).

A study conducted by Tzouramani and Mattas (2003) revealed the financial results of GH tomato production in Greece using NPV, IRR, Benefit-Cost Ratio (BCR), and Profitability Index (PI). These indicators for Crete were as follows: The NPV is

$28503, the IRR is 23%, the BCR is 1.62, and the PI is 1.21. The same figures for Northern Greece were $4780, 19 percent, 1.48, and 1.03, respectively. The authors revealed that a modern GH is acceptable under the condition of providing subsidies for initial investment costs. They used the Monte Carlo simulation technique and found it positive. An article published by Engindeniz and Gul (2009) compared the soil-based and soilless systems in the cultivation of cucumbers under GHs. They found the net return by subtracting the total cost from the total revenue in both methods. In the soilless method, it was 1.84 euros, while in the soil-based method, it was 1.48 euros per metre square.

Armenia et al. (2013) analysed the protected cropping structure of Eastern Visayas, Philippines. Vegetable cultivation in this region was difficult due to heavy rain and winds. GHs were the most prominent method to protect crops from bad weather. Their study focused on the economic viability of GH cultivation and promoted measures to promote the GH cropping system in the area. For the study, they chose 18 farmer cooperatives involved in the project. A three-year summary of average receipts, expenses, and gross margins with and without protective structures was examined. For a 200-square-metre protected structure, the Net Present Value (NPV) was 30000 pesos and the Internal Rate of Return (IRR) was 100 percent. Cropping under protected structures generated 84 percent more revenue than cropping without a structure. They concluded that cropping under protected structures was economically viable, though crop yields differed.

An article written by Diab, Magdi, Mousa, and Hassan (2016) analysed the GH experiment of cucumber cultivation in Aswan, Egypt. This experiment was conducted in a 4200 sq. m. area to test the economic feasibility of the practice of GH cucumber cultivation. In it, they found that the average net profit was thirteen times higher than that of open-field cultivation. The major financial indicators were an NPV of 223353 L.E. and an IRR of 48.11 percent, while the current interest rate was only 11 percent. The gross profit margin was calculated as the difference between total revenue and total variable costs. The net return was calculated by subtracting total production costs from gross revenue. It costs 126,000 L.E. up front to build a GH that is 4200 square metres in size; another 186,000 L.E. goes towards upkeep each year; the variable cost is 29617 L.E.; and the fixed cost is 52170 L.E. The GH system resulted in a gross margin of 84383 L.E. for cucumber cultivation, while open fields had a gross margin of only 15047 L.E. This article contrasts greenhouse (GH) cultivation with open-field production of cucumbers, highlighting the latter's greater long-term costs while highlighting the former's greater short-term benefits.

An article by Sanwal, Patel, and Yadav (2004) stated the benefit-cost ratio for a 100 sq. m. polyhouse utilising fully hired labour, 50 percent hired labour, and fully family labour was 1.79, 2.53, and 4.3, respectively. However, the total area of cultivation of vegetables under GH in India is low compared to major countries in the world.

Another study by Murthy, Prabhakar, Hebbar, Srinivas, and Prabhakar (2009) analysed the economic feasibility of vegetable production under polyhouses as a case study of two major crops, such as capsicum and tomato, and its economic feasibility in a naturally ventilated polyhouse at the Indian Institute of Horticultural Research, Bangalore, during 2002–2004. They generated data using the cost accounting method from 2001 to 2004. They used evaluation methods such as payback period, BCR, NPV, and IRR. They discovered that capsicum had a payback period of less than two years, with an NPV of 3.23 lakhs, a BCR of 1.8, and an IRR of 53.71 percent. In the case of tomatoes, the figures were as follows: a payback period of more than 6 years, an NPV of less than 1.13 lakhs, a BCR of 0.69, and an IRR of less than 11.5 percent. All these proved that tomato production under the polyhouse was not economically feasible. However, a study by Mangal, Bhattacharya, Sudan, and Aswathi (2015) had a different story to tell. According to them, in India, open-field tomato cultivation yield on average was 180.6 quintals per hectare in 2013–14. It multiplied by five to ten times under protected cultivation.

According to an article written by Sanjeev, Patel, Saravaiya, and Desai (2015), the introduction of naturally ventilated polyhouses (NVP) helped overcome many problems of open field cultivation. They studied the economic aspects of cucumber cultivation under NVP in a 1000 sq. m. area. They found that there was a financial return of Rs. 3,71,642 and Rs. 1,64,723 in 2013 and 2014, respectively, without considering the subsidy given by the government. The BCR for 2013 and 2014 was 1.36 and 0.55, respectively. If subsidies were taken into consideration, the values increased to 2.03 and 2.17, respectively. They concluded that the new method of cultivation opened new opportunities for small farmers in the state of Gujarat. However, a different story by Chahal (2016) said that the breakeven output of capsicum was between 3807 kg in 500 sq. m and 12215 kg in 2000 sq. m polyhouses. The cost of production of capsicum had a negative relationship with the size of polyhouses. NPV was negative and IRR was less than 10 percent for both tomato and capsicum in polyhouses with sizes less than 1000 sq. m. for both subsidised and unsubsidised cases. Under subsidised conditions, polyhouses with a size of less than 500 sq. m. were not economical. Carnation crops, on the other hand, were feasible and profitable, with an IRR ranging from 27 to 33 percent and a BCR ranging from 1.45 to 1.57. Lack of technical know-how, irrigation facilities, hurdles in the sanctioning of subsidies, and remote markets were the prominent challenges faced by the polyhouse farmers in the area. Reddy (2017) revealed that polyhouse projects are economical, as their IRR ranged from 17 percent to 32 percent.

The net return under protected conditions was higher as compared to open field conditions. The figures were Rs. 1725 per 250 sq. m. and 12907 per 500 sq. m. for tomatoes and Rs. 246 per 250 sq. m. and 15792 per 500 sq. m. for capsicum. All of these revealed that vegetable cultivation under the polyhouse has a higher yield compared to open-field cultivation. Higher wages, frequently affected by diseases, a lack of technical know-how, etc. are the major problems faced by the vegetable growers in the region. Singh (2017) compared the cultivation of vegetables under open and protected conditions in the Solan district of Himachal Pradesh. The net return under protected conditions was higher as compared to open field conditions. The figures were Rs. 1725 per 250 sq. m. and 12907 per 500 sq. m. for tomatoes and Rs. 246 per 250 sq. m. and 15792 per 500 sq. m. for capsicum. All these revealed that vegetable cultivation under the polyhouse has a higher yield compared to open-field cultivation. Senthilkumar, Ashok, Chinnadurai, & Ramanathan (2018) examined the economic and financial feasibility of polyhouse cultivation of capsicum in the Krishnagiri district of Tamil Nadu. The payback period was less than three years. The other indicators were: the annual average net return of 15.29 lakhs; the NPV at a 12 percent discount rate for a five-year period of 5.78 lakhs; the BCR of 1.24; and the IRR of 25 percent for 4000 sq. m. This study revealed that the production of capsicum in a polyhouse is highly feasible and profitable. The payback period was 18–24 months. This project has created awareness in the locality about GH farming and the possibility of higher returns for the farmers. Moreover, the GH technology under precision farming increased crop yield by 3 to 4 times in the case of tomatoes and 4 to 5 times in capsicum compared to the traditional method of open field cultivation.

Lakshmi, Prema, Ajitha, and Pradeepkumar (2017) studied the economic feasibility of GH farming of two crops, such as salad cucumber and yardlong bean. The economic indicators of salad cucumber were a payback period of 3.2 years, an NPV for 10 years of 5.3 lakh per 400 sq. m., a BCR of 1.5 at a 12 percent discount rate, and an IRR of 42 percent. The same figures for yardlong beans were: payback period 5.2 years, NPV 1.04 lakhs/400 sq. m., BCR 1.1, and IRR 19 percent. All these figures illustrate that the cultivation of salad cucumbers in GH is far more beneficial.

However, the advisory, supervisory, and technical support roles of the government in the adoption of this technique have not been studied so far. Questions about the suitability of this model remain unanswered. A few cases of heavy losses and cases of success exist side by side. Nandakumar T. (2018) reported the bitter experience of a few polyhouse farmers in Kerala. Polyhouse farmers incur high costs for seeds, water-soluble fertilisers, pesticides, and biocontrol agents imported from other states. Unsuitable weather conditions prevailing in the state were the fourth reason for the failure, according to Mr Jose George, a farmer from Kothamangalam. The assistance from SHM was not received properly. The rates were last revised in 2014, but prices shot up every year in the subsequent period. It puts an extra burden on the farmers.

The study conducted by C. Nalin Kumar revealed that various types of support should be given to the polyhouse farmers in a continuous manner, and new initiatives should be implemented only after a cautious study of costs, suitability to weather conditions, and marketability of the product (Kumar, 2018).

A study was conducted by Harisha et al. (2019) during 2016–17 to analyse the economic viability of vegetable production under shade net in a few taluks of the Kolar district of Karnataka by involving 80 vegetable growers. Major crops used for analysis were capsicum and tomato, using project analysis tools such as net present value (NPV), benefit-cost ratio (BCR), internal rate of return (IRR), and payback period (PBP). The cash flow analysis was calculated based on estimated cash outflows and inflows for both capsicum and tomato crops over the last 15 years. The study revealed that investment in shade nets for capsicum (BCR = 1.69) cultivation is more profitable than tomato (BCR = 1.48). The fixed costs and labour costs for the cultivation of both crops were found to be approximately the same. The variation in income of both crops was mainly due to the stable price of capsicum as compared to tomatoes in the market. Capsicum had a net present value of Rs. 2918455, a payback period of two years, and an IRR of 22.25 percent. The same figures for tomatoes were Rs. 1216138, four years, and 35.35 percent, respectively. Therefore, it is advisable that farmers try to adopt shade net technology. It provides an opportunity to make agriculture a profitable activity.

Franco et al. (2018) studied the economic feasibility of selected vegetable cultivation under polyhouses in the Chittoor block of Palakkad district. Data from all 15 hi-tech polyhouse farmers in the block was collected using a detailed and in-depth questionnaire. Out of those 15 polyhouses, 8 were managed by women's self-help groups (SHG) and the rest by individual farmers. The study also discovered that polyhouses established by SHGs were better managed than private farms. The costs and returns are given in per-polyhouse and per-ha terms for comparison. In capsicum cultivation, the gross return was highest in SHG, followed by private farms. The yield also showed a similar trend. The yield of yardlong beans was higher for SHG-run polyhouses than for private farms. The private farms that cultivated cucumbers in polyhouses got the very best yields, irrespective of farm categories. The gross returns were highest, and the cost was lowest for individual farmers. SHG-based polyhouse cultivation was found to be more labour-intensive than that of private firms. The farmers here likewise rely on the state government and the SHM for building polyhouses. The state government, through the People's Plan, gives a total of Rs. 467 per sq. m. for setting up polyhouses. Another supporting organisation is called the State Horticulture Mission (SHM), which gives an amount of Rs. 374.5 per sq. m. The rest of the amount of nearly Rs. 374.5 per sq. m. must be borne by the farmers themselves. These linkages are working adequately in the testing region, which is apparent from the fruitful execution of the fifteen polyhouses set up there. The important indicators of the economic feasibility of this venture can be summarised as NPV Rs. 131801 (SHG Rs. 1306989 and Individual Rs. 133631), BCR 2.17 (SHG 2.19 and Individual 2.17), and IRR 37.51 (SHG 37.80 and Individual 37.29) if the subsidy is taken into consideration. But the figures became NPV Rs. (-) 49392 and BCR 0.83 if the subsidy was not taken into consideration. According to the data, subsidies are an important factor in bringing polyhouse farming into profitability.

Hena (2017) analysed the important factors for the adoption of polyhouse farming in the Thrissur district. Farmers' awareness of the practices, predicted economic benefits, and willingness to take risks were all major factors in the adoption of poly-house farming. The worry of an initial drop in yield was the main cause of poor adoption. There is a need for public awareness initiatives to encourage young people to participate in polyhouse farming. According to the study's findings, farmers were moderately supportive of polyhouse farming.

2.3.14 Sustainability of Greenhouse Vegetable Farming

Though the GH method of vegetable cultivation was beneficial, it had a few sustainability issues. Environmental degradation as a consequence of the usual practices of farmers is a major concern. The disposal of transparent covering materials, excessive use of fertilisers, etc., create the problem.

According to Wainwright, Jordan, and Day (2014), though production within GHs is highly economically efficient, it poses special environmental threats. The intensity of the use of resources is very high. There are around 800,000 ha of GHs worldwide, and they can be classified as northern type and southern type. The northern type is generally high in technology, while the southern type is plastic-covered houses with simple or no heating systems, containing a low level of technical complexity. The former has a significantly higher rate of CO2 emissions than the latter due to the combustion of natural gas for heating. The southern type is also not free from environmental threats. The horticulture industry in the southern region of Spain has caused the rapid depletion of surface water and freshwater aquifers. Intensive levels of biocide and fertiliser inputs also contributed to the degradation of land and water quality, which caused a reduction in biodiversity in nearby aquatic systems (Wolosin, 2006). Intensive horticulture has contributed to global warming and climatic change through the processes of energy combustion, transportation, cold storage, and the use of inorganic inputs. GH crops have large environmental footprints, as do those that emit a large quantity of GHGs, such as milk. As GHs are responsible for higher emissions of CO2, energy conservation and efficient use of resources must be promoted. For this, financial incentives should be given. As greenhouses are responsible for the highest levels of CO2 emissions within horticulture, energy conservation and efficiency must be optimised to reduce current levels. The use of a closed irrigation system with biological filtration can reduce the use of water and fertilisers by 25 to 40 percent. IPM is suggested as a way to protect the environment from the danger that pesticides pose.

According to a study by Yang et al. (2016), the sustainability of GH production of vegetables is a prime concern in China to feed the growing population. This study examined the sustainability of GH vegetable farming based on selected indicators touching on economic and socio-institutional perspectives. 91 farm households from six typical GHs were surveyed to collect data. According to the results, heavy accumulations of N, P, Cd, Cu, Pb, and Zn were found in the soil and irrigation water. The consequences were a decreased yield in traditional farming and a lower farmers' income. The lack of complete implementation of the subsidy policy is the major reason for the excessive use of fertilizers. Socio-institutional factors such as a lack of unified farm management, small family business models, and poor agricultural extension services also contributed to these phenomena. For the sustainability of the GH vegetable production system, two key aspects should be present: first, it is vital to reduce environmental pollution and resultant health risks through integrated nutrient management and a strategy of low metal accumulation in the soil; second, a conversion of cooperative and small-family business models of GH vegetables to enterprise models is beneficial. It is necessary to unify agricultural supply management and improve the efficiency of extension services. This can stabilise vegetable yields and consequently improve farmers' income.

Srinivasulu, Singh, Magray, and Rao (2017) studied the constraints and prospects of the protected method of cultivation of vegetables in the Kashmir region. GHs, comprising glass and polyethylene houses, are becoming popular both in temperate and tropical regions. The commercial mode of cultivation of vegetables is promoted in the Leh and Ladakh regions of the state. Programmes in the VIII and IX plans contributed to the promotion of GHs in the region. The GH cultivation method has many benefits, such as ease of management, off-seasonality, and protection from biotic and abiotic problems. However, this system of vegetable cultivation is in its infant stage and has not yet gained popularity in the region. The high cost of construction and the non-availability of components are the major constraints. Many of the components, such as fibreglass, cooling pads, fans, etc., have to be imported at a high cost. Other problems with this system are that it does not have a standard structure, farmers don't know about it, and there aren't enough research programmes on it.

Kumar, Chauhan, Tanwar, and Grover (2018) have done a study to examine the status and constraints of polyhouse vegetable cultivation in Haryana. Purposively, Karnal district was selected for study due to the predominance of vegetable cultivation in the area under polyhouses. Personal interviews were conducted using specially designed schedules to collect primary data. The analysis of the data was done using simple tools like averages and percentages to infer conclusions. The findings revealed that the major constraint of polyhouse cultivation is the short life of the polyethylene covering sheet (92%), which was damaged during high wind flow. Insect attack was the next major problem (90%), followed by the high cost of fertilisers (82.5%) and the high price of seeds (77.5%). Besides these cultivation constraints, there were a number of marketing constraints for polyhouse products.

Lack of a minimum support price was the main problem for polyhouse farmers (92.5%), followed by high price fluctuations (87.5%) and inadequate market information (75%). The high cost of transportation, malpractices in weighing machines, and unavailability of quality packing materials were the other major problems with polyhouse cultivation in the area.

According to Ghanghas, Malik, and Yadav (2018), though India is the second-largest producer of vegetables in the world after China, its requirements for vegetables are increasing quickly because of the ever-increasing population. To face adverse weather, small and fragmented land, and increased demand for quality vegetables, it was necessary to adopt a polyhouse system of cultivation. In this article, they examined the major advantages and challenges of the polyhouse farming system. For this study, they used a multistage sampling technique. Two districts, namely Karnal and Panipat, were purposefully selected. Twenty-five polyhouse farmers were selected randomly from the list collected from the District Horticulture Office. A total of 50 polyhouse farmers were interviewed directly to collect data. The data were analysed by applying statistical tools such as frequency, percentage, weighted mean, and rank order. The findings revealed that there were a number of benefits to this system, such as enhanced production and productivity, the economy of water, energy, and labour, and high-quality and clean products. However, there were numerous issues with polyhouse cultivation as well. The population explosion of minute insects, the frequent occurrence of storms, and the deficiency of cold storage facilities were prominent among them. The insects attacked almost all farmers, while the high cost of storage and transportation affected 94 percent of farmers, followed by the frequent occurrence of storms (92 percent), the high cost of seeds (92 percent), a lack of knowledge about the value addition process (90 percent), and a high initial cost (86 percent). The other problems were the high cost of the nursery (86%), the lack of ongoing technical guidance (84%), the lack of marketing knowledge (84%), and the poor quality of the cladding material (82%).

Kaur et al. (2018) conducted a study to analyse the prospects of protected vegetable cultivation in Punjab. 150 respondents from six districts such as Amritsar, Gurdaspur, Sangrur, Moga, Jalandhar, and Kapurthala were taken by probability proportion for this study. The personal interview method was used for data collection in connection with the prospects and satisfaction of the protected vegetable farmers. They found that this method of cultivation has gained importance in the state since 2009. The majority of the respondents adopted this technique during the period from 2009 to 2013. One-third of the respondents indicated a willingness to expand the area of cultivation, while 45 percent indicated a desire to maintain the current area because they are unable to handle cultivation in more areas. The majority of the respondents preferred polyhouses, followed by net houses. Most of the respondents are satisfied with this method of cultivation, as it is a profitable activity for farmers as both off-season production and high yields are possible.

In a life cycle assessment study of tomato production, Boulard et al. (2011) examined the environmental impact of greenhouse tomatoes. Techniques were designed for the study of the environmental performance of the protected cultivation system. This study revealed that GH heating for off-season production generated the main impact, including toxicology and ecotoxicology. The average impact was 4.5 times greater for heated GHs per kg of tomato. This fact is valid even if assessed per euro of tomatoes produced. It was estimated that the impact of pesticides, particularly fungicides, was lower in heated GHs than in cold tunnels. Moreover, pesticides in tunnels had a 3- to 6-fold higher impact in terms of terrestrial or aquatic ecotoxicology than in human toxicology. Green waste, such as the pruning waste and the plants at the end of the season, amounts to about 17 kg per sq. m. for soilless cultivation and 13 kg per sq. m. for soil-grown crops. Composting is complicated with plastic twine and clips.

Nair D.S. (2021) conducted a field experiment at the instructional farm of KCAET in Tavanur, Kerala, from April to June 2021. The microclimate and performance of CO-1 (Amaranthus green variety) were compared in both cleaned and uncleaned greenhouses (greenhouses without cleaned cladding material). The cleaned greenhouse had greater mean monthly values of light intensity and temperature than the dirty one, whereas the old greenhouse had higher relative humidity. As a result, crop growth parameters such as plant height, number of leaves, number of branches, and average yield per plant were higher in the cleaned greenhouse than in the old one.

Polyhouses are causing concern because of excessive pesticide residues in the food as a result of indiscriminate chemical use at a time when "organic" is the catchword. In fact, the long-term viability of poly-house farming is in jeopardy since a large number of them have closed owing to soil degradation, nematode—a type of dangerous soil bacterium—and fungus attacks, which have resulted in huge crop destruction (Kumar, 2018).

2.4 Research Gap

1. High-tech farming is becoming more popular in various countries around the world. It is also profitable in a number of Indian states. But its full potential has not been looked into enough in Kerala, which is a great place for this type of farming.

2. Kerala's high-tech vegetable growers come from diverse socio-economic backgrounds. How this diversity affects the amount of land, production, productivity, and profit in high-tech agriculture has not been found studied in depth.

3. High-tech farming is not a standardised practice. The number of equipment used, the technology, the size of the farm, and the method of cultivation all differ. Because of this, it is very important to find out how this difference affects production, productivity, and profit.

4. There are numerous limitations and challenges to high-tech farming. The most important are the technical and economic ones. Because of this, it is very important to investigate the biggest technical and economic problems that high-tech vegetable farming in Kerala faces.

2.5 Conclusion

Consumption of vegetables is essential for human immunity and high health status. Their permanent availability has been ensured by agriculture since the formation of human civilization. What has traditionally existed and is still important is open-field farming. But this method also has its own limitations. Most importantly, it is not possible to ensure the availability of vegetables in areas where cultivation is not possible throughout the year. In addition, high levels of pesticide residues are present in the products. As a solution to both, high-tech farming methods in greenhouses have been adopted in various countries. Although its methods vary from country to country, the general nature of providing protection from bad weather and pests can be seen everywhere. The experience of different countries as well as the experience of states that have implemented it in India shows that high-tech vegetable farming is technically and economically better than open farms. However, it can be seen that no in-depth study has been done in this regard in Kerala. A few studies have already been done by agricultural scientists. Their main focus was to emphasize the technical superiority of GH farming. Naturally, the need for a study focusing on economic applicability can be seen here. On the basis of the literature survey, a few research gaps have been found and listed.

CHAPTER III

HIGH-TECH VEGETABLE FARMING: OVERVIEW

3.1 Role of Agriculture in the World Economy

Based on 179 countries, the average share of the agriculture sector in 2019 was 10.36 percent. Sierra Leone had the highest value of 58.15 percent, while San Marino had the lowest value of 0.02 percent. Based on 178 countries, the average value added in 2019 was 19.02 billion US dollars. China had the highest value: 1020.11 billion US dollars (*The World Bank*, 2020).

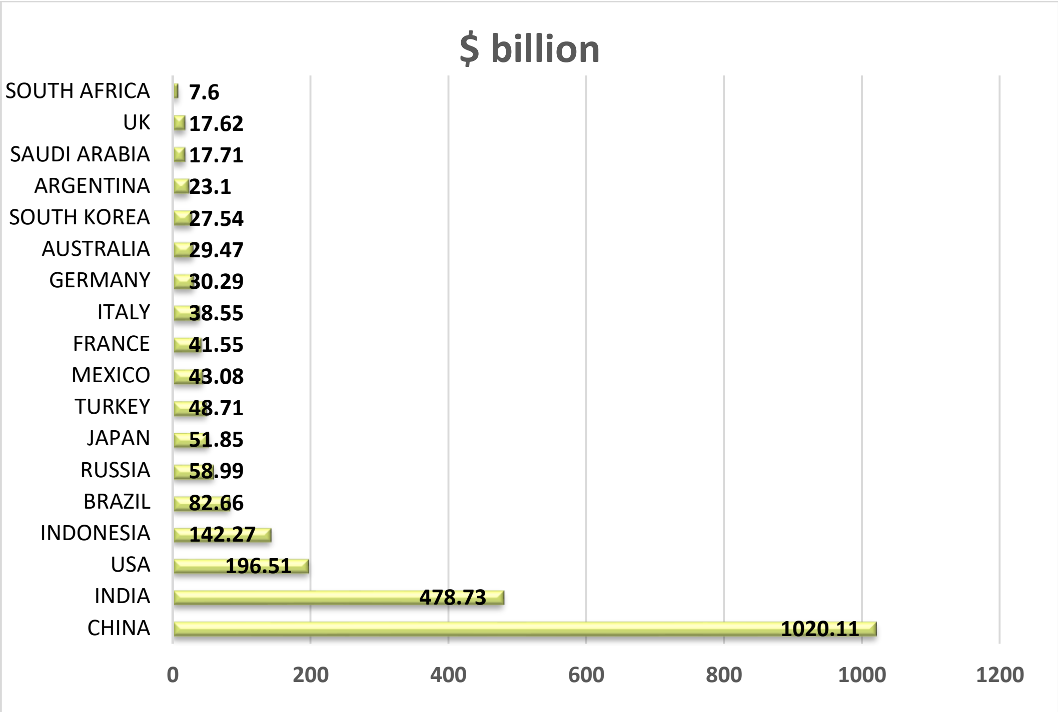
Figure 3.1

Contribution of Agriculture Sector to GDP in Various Countries

Source: World Bank national accounts data, and OECD National Accounts data files.

Figure 3.2

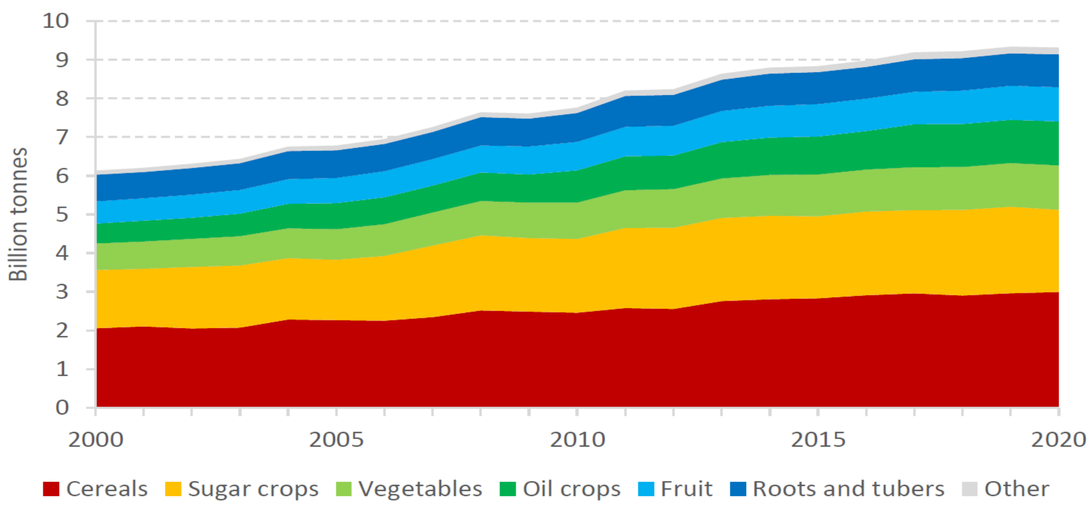
Gross Value Added of Agriculture Sector in G 20 Countries (Billion US $)



Source: World Bank national accounts data, and OECD National Accounts data files.

3.2 Production of Various Crops

Figure 3.3
Global production of crops by commodity group



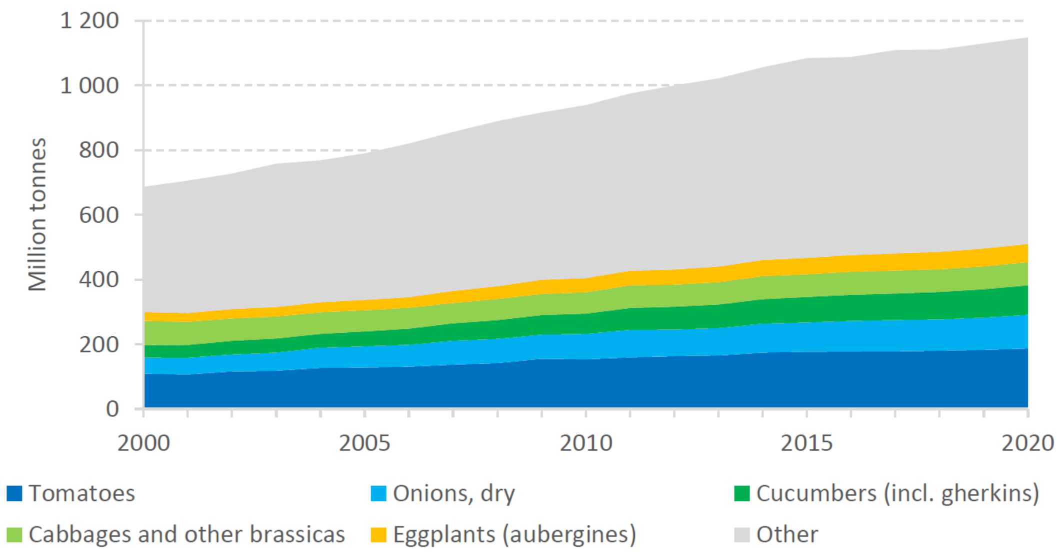
Source: FAO. 2021. Production: Crops and livestock products. In: FAO. Rome. Cited March 2022. https://www.fao.org/faostat/en/#data/QCL

Global primary crop production increased by 52 percent between 2000 and 2020, reaching 9.3 billion metric tonnes in 2020. This is 3.2 billion tonnes greater than in the year 2000. Cereals were the primary group of crops produced in 2020, accounting for a little less than one-third of the total, followed by sugar crops (23 percent), vegetables and oil crops (23 percent), and other crops (12 percent each). Fruits, roots, and tubers collectively contributed 9–10 percent of total productivity. Between 2000 and 2020, oil crop output increased at the fastest rate, increasing by 120 percent from 0.5 billion metric tonnes to 1.1 billion metric tonnes.

3.3 Global Production of Vegetable Crops

Figure 3.4

Global Production of Vegetables by Main Commodities



Source: FAO. 2021. Production: Crops and livestock products. In: FAO. Rome. Cited March 2022. https://www.fao.org/faostat/en/#data/QCL

During the period spanning from 2000 to 2020, there was a notable surge of 65 percent in worldwide vegetable production, resulting in a significant expansion of 446 million MT, ultimately culminating in a cumulative output of 1128 million MT. Significantly, within the wide range of cultivated vegetables, five distinct species emerged as the primary contributors: tomatoes accounted for 16 percent, onions held a nine percent share, cucumbers commanded eight percent, cabbages encompassed six percent, and eggplants constituted six percent. The combined contribution of these five prominent vegetable kinds constituted a significant proportion, ranging from 42 to 45 percent, of the total vegetable production.

Notably, during this particular period, significant transformations were noticed in the realm of vegetable cultivation. The market share of onions, cucumbers (including gherkins), and eggplants had notable growth. On the other hand, cabbages experienced a significant decline, reducing their prior contribution by almost 50 percent. Conversely, the production of tomatoes had a very consistent trend across the specified time frame.

China has emerged as the dominant leader in different vegetable categories in terms of geographical distribution of output. China has emerged as the foremost global producer of tomatoes, commanding a significant share of 35 percent in overall tomato production. Moreover, the nation additionally assumed a prominent position in the cultivation of cucumbers, accounting for a remarkable 80 percent of the global cucumber output. China was a prominent producer of cabbages, making a substantial contribution of 48 percent to the overall global production of this vegetable. China has emerged as a leading producer of eggplants, accounting for a significant 65 percent of the total global eggplant production.

In addition to China, India has also played a significant role in the global production of vegetables. India has achieved the prominent status of being the foremost producer of onions, contributing a significant proportion of 26 percent to the overall global onion production. This statement highlights the varied geographical inputs to the worldwide vegetable market in the context of its expansion and transformation.

3.4 Methods of Vegetable Cultivation

Mainly, there are two methods to cultivate vegetables: conventional open-field cultivation (COFC) and high-tech cultivation under greenhouses (HCG). The former is a traditional and dominant system, whereas the latter is a modern and promising system that is not widely used worldwide.

3.4.1 Conventional Open Field Cultivation (COFC)

Open-field cultivation is a traditional farming approach. The vast majority of farmers cultivate their crops in open fields. This agricultural method comes with its own set of difficulties. Farmers must deal with climate change, natural disasters, pest and disease attacks, deteriorating soil health, and dwindling water supplies. The soil must be nutrient-rich, disease-free, pH-balanced, and have a healthy soil composition to be successful. More land under vegetable crops, hybrid seeds, and improved farming methods are the most prominent approaches to increasing output. Managing environmental risks is critical to achieving success. To keep the plants alive, pesticides, insecticides, fungicides, and herbicides must be frequently used in large quantities. We often hesitate to purchase pesticides because we are aware of the risks associated with consuming them, yet we do not hesitate when purchasing vegetables at the market. Moreover, the COFC is subject to diminishing returns to scale.

3.4.2 High-tech Cultivation under Greenhouses (HCG)

According to UN estimates, the world's population will reach 9.7 billion by 2050. According to various estimates, India will house between 1.6 and 2 billion of these people (Ghosh, 2012). The demand for horticultural produce is expected to rise at a rate greater than 3% per year (Chand, 2008; Ghosh, 2012). In contrast, year-on-year growth in horticultural crop production has slowed from 7.8 percent in 2010–11 to 2.1 percent in 2015–16. If these trends continue, they will cause a significant gap in the demand and supply of horticultural crops. As predicted in a NAAS policy paper (Chadha, 2001) and later in a NAAS report, the only way out of this situation will be to use high-tech horticulture.

Modern agricultural methods that increase food production often have severe consequences for other ecosystem functions like water conservation and soil fertility (Foley et al. 2005). However, by producing more food while utilising less land and minimising overall negative environmental impacts, sustainable intensification of agriculture could assist in solving these concerns (Godfray et al. 2010).

A greenhouse is a structure made of galvanised steel and covered on all sides with agricultural plastic film or shading net, in which plants can be grown in controlled and optimal climatic conditions. This technology is the science that provides favourable environmental conditions for plants. It allows the farmer to manage the environment in which his or her plants develop. Not only will it keep pests and birds out, but it will also give him better control over temperature, humidity, irrigation, and light. The farmer can provide the perfect circumstances for the plants to thrive without using dangerous pesticides, ensuring that the vegetables are of high quality. This system of vegetable cultivation is a promising solution for agricultural intensification.

A polyhouse, often known as a greenhouse, is a building or structure constructed of translucent materials such as glass or polyethylene. The size of the construction can range from small shacks to large structures, depending on the demand. Above all, a greenhouse is a glass structure whose interiors warm up when exposed to sunlight because the structure prevents greenhouse gas from escaping. When it's freezing outside, the temperature inside is warm enough for the plants to survive. A polyhouse is a sort of greenhouse, or, to put it another way, a smaller version of a greenhouse with a polyethylene cover. Polyhouse farming is a popular greenhouse method in developing nations like India because of its inexpensive construction costs and ease of upkeep. Although a polyhouse is less expensive than a greenhouse, the latter is more durable (Toppo, 2021).

A greenhouse operator is a person who is responsible for carrying out various greenhouse operations. The individual is in charge of various operations involved in the cultivation of seedlings and plants in a controlled environment. This job requires the individual to work strictly according to the supervisor's instructions. The individual should be hardworking and have a desire to learn new things. He or she should also be clear and goal-oriented. The individual should also be able to demonstrate proficiency in the use of various tools and the keeping of necessary records (Agriculture Skill Council of India, 2016).

3.4.3 Hydroponics

The word hydroponics comes from two Greek words: "hydro", meaning water, and "ponos", meaning labour. The U.S. Army used hydroponic culture to grow fresh food for troops stationed on infertile Pacific islands during World War II. By the 1950s, there were viable commercial farms in America, Europe, Africa, and Asia. Plants can be grown "hydroponically" with or without the use of an artificial medium in a liquid nutrition solution. Expanded clay, coir, perlite, vermiculite, brick shards, polystyrene packing peanuts, and wood fibre are examples of commonly used materials. It is now accepted that hydroponics is a practical way to grow ornamental crops like herbs, roses, freesia, and foliage plants, as well as vegetables such as tomatoes, lettuce, cucumbers, and peppers (Dunn & Shreshtha, 2013).

3.4.4 Aeroponics

The method known as aeroponics involves growing plants in an atmosphere without soil or spraying the roots with hydroponic solutions that are suspended in the air. It doesn't use a medium made of soil or aggregate. A nutrient-dense fluid is sprayed on the plant roots at regular intervals while the plant roots are suspended in a dark cage in an aeroponic system. Because roots receive enough oxygen in this system, growth can occur more quickly (*Aeroponics*: *An Overview | ScienceDirect Topics*, n.d.).

3.4.5 Aquaponics

Aquaponics combines hydroponics (the growing of plants without soil) and aquaculture (the raising of fish and other aquatic animals) in a single recirculating environment. In aquaponics, the nitrifying bacteria transform fish waste into nutrients for the plants. For growth, plant roots absorb these nutrients. In exchange, the fish receive clean, filtered water from the plant roots. In aquaponics, fish are kept in a fish tank while plants are grown in a grow bed. Millions of naturally occurring helpful bacteria in the grow bed convert the ammonia in the nutrient-rich water from the fish tank that contains fish waste into nitrites and ultimately into nitrates (*What Is Aquaponics and How Does It Work? Go Green Aquaponics*, n.d.).

3.5 Types of Greenhouses

Different types of greenhouse structures are used for crop production. In general, there is not a single type of greenhouse that can be considered superior. Different types of greenhouses are designed to meet specific needs. Below is a summary of the different types of greenhouses based on shape, usability, material, and construction:

3.5.1. Type of Greenhouses Based on Shape

A. **Sawtooth type Greenhouse:** There is provision for natural ventilation in this type.

B. Lean-to-type Greenhouse: When a greenhouse is built against the side of an existing structure, it is known as a lean-to structure.

C. Quonset Greenhouse: The pipe arches, or trusses, in this greenhouse are supported by pipe purling that runs the length of the greenhouse. Polyethylene is commonly used as a covering material for this type. As a result, they are usually less expensive.

D. Ridge and furrow type Greenhouse: In this style of design, two or more frame greenhouses are joined along the length of the eave. They are successfully employed in northern European countries and Canada, and they are well suited to Indian conditions.

E. Uneven span type Greenhouse: This sort of greenhouse is built on a mountainous site. The roofs are of different breadth, allowing the structure to adjust to the hill's side slopes.

F. Even span type Greenhouse: The even-span structure is the most common and full-size structure, with equal pitch and width on both roof slopes. This idea is for a small greenhouse that is built on flat ground.

G. Gable-roofed Greenhouses: They are one of the most popular greenhouse types. They get enough sunlight while still having enough room to grow a lot of plants. Furthermore, the farmer can move around freely while caring for the garden because of the straight walls and high roof.

Figure 3.5

A: Sawtooth Greenhouse **B: Lean to type Greenhouse**

https://www.greenecosystem.in/

Source: http://agrimenia.blogspot.com/

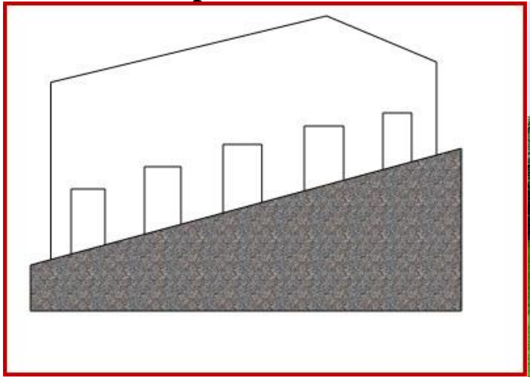
C Quonset Greenhouse

source: www.gothicarchgreenhouses.com

D. Ridge and Furrow Greenhouse

Source: www.nafis.go.ke

E. Uneven Span Greenhouse



Source: http://agrimenia.blogspot.com/

F. Even Span Greenhouse

https://www.istockphoto.com/photo/in-a-large-greenhouse

G. Gable type Greenhouse

Source: https://ecoslider.com/

3.5 2. Types of Greenhouses Based on Construction

The structural material has a significant impact on the type of construction

A. Structures made of wood: In general, only wooden-framed buildings are used for greenhouses with spans smaller than six meters. Without the use of a truss, the side posts and columns are made of wood. Pinewood, bamboo, and other similar materials are typically used since they are inexpensive and provide the requisite strength. Locally available wood that is strong, durable, and easy to work with can also be used for building.

B. Structures made of pipes: When the clear span is roughly 12 m, pipes are used to construct greenhouses. Pipes are used for making side posts, columns, cross ties, and purlins in general. The trusses are not used in this design.

C. Structures with truss frames: Truss frames are used if the greenhouse span is more than or equal to 15 meters. A truss is made up of rafters, chords, and struts that are welded together from flat steel, tubular steel, or angular iron. Struts are compression support members, while chords are tension support members. Each truss is fastened to angled iron purlins that run the length of the greenhouse. The majority of the glasshouses use truss frames, which are ideally suited for pre-fabrication (*DMGH: Lesson 1: History and Types of Greenhouse*, n.d.).

3.5.3. Greenhouse Types Based on Covering Material

The primary and most important component of the greenhouse structure is the covering materials. Covering materials have a direct impact on the greenhouse effect inside the structure as well as the air temperature inside. The types of frames and methods of attachment vary according to the covering material. Glass, plastic film, and rigid panel greenhouses are the three types of greenhouses based on their covering materials.

A. Greenhouses made of glass: Prior to 1950, only greenhouses with glass as the covering material existed. The use of glass as a covering material has the advantage of increasing the intensity of the interior light. These greenhouses have a higher rate of air infiltration, resulting in lower interior humidity and better disease prevention.

B. Greenhouses made of plastic film: In this type of greenhouse, flexible plastic films such as polyethylene, polyester, and polyvinyl chloride are used as covering materials. Plastics have become popular as greenhouse covering materials because they are inexpensive and have lower heating costs than glass greenhouses. The main disadvantage of plastic films is their short lifespan.

C. Greenhouses with rigid panels

In this type of greenhouse, flexible plastic films such as polyethylene, polyester, and polyvinyl chloride are used as covering materials. Plastics have become popular as greenhouse covering materials because they are inexpensive and have lower heating costs than glass greenhouses. The main disadvantage of plastic films is their short lifespan.

3.5.4 Greenhouse Types Based on Cost

Greenhouses can be divided into three main categories based on cost. Cost is mainly determined by the level of facilities and technology used.

A. Low-tech or low-cost Greenhouses: A low-cost greenhouse is a simple structure made of locally accessible materials like bamboo and wood. The cladding materials are made of UV film. There is no specific control equipment for regulating environmental conditions inside the greenhouse, unlike traditional or high-tech greenhouses. However, simple approaches are used to increase or decrease temperatures and humidity. Even the intensity of light can be lowered by using shade materials such as green nets. During the summer, the temperature can be lowered by opening the side walls. This type of structure is used for agricultural production as a rain shelter.

B. Medium-tech Greenhouses: Due to the low investment, greenhouse users prefer a manual or semi-automated control system. Galvanised iron (GI) pipes are used to construct this sort of greenhouse. With the help of screws, the canopy cover is spread over the structure. To endure wind disturbance, the entire structure is firmly attached to the ground. The temperature is controlled by exhaust fans with thermostats. Evaporative cooling pads and misting arrangements are also used to keep the greenhouse at a comfortable humidity level. Because these systems are semi-automatic, they require a lot of attention and care, and maintaining a consistent environment during the cropping period is challenging and time-consuming. These greenhouses are appropriate for arid and mixed climates.

C. High-tech Greenhouses: To tackle some of the challenges of a medium-tech greenhouse, a hi-tech greenhouse has been developed in which the complete equipment, which controls the environmental conditions, is assisted to operate with the help of a computer-based automated system (*Horticulture: Greenhouse Cultivation*, n.d.).

3.6 Instruments Commonly Used to Diagnose Greenhouse Environment

1. **Thermometer:** Air temperature can be measured with a common thermometer. An infrared thermometer measures surface temperature.

2. **Compact sling psychrometer:** It is used to measure humidity under the greenhouse.

3. **Hygrometer:** Relative humidity can be measured directly by using a hygrometer.

4. **Anemometer:** Air speed is measured with it**.**

5. **Portable CO_2 monitor:** To check the level of carbon dioxide under the greenhouse.

6. **Fan and Pad:** Evaporative cooling is a tool for lowering greenhouse gas emissions. A "fan and pad" system draws air through evaporative cooling

pads using exhaust fans. This technique takes advantage of the cooling effect produced when water evaporates to cool the air as it is drawn through the pad.

7. **Sensor probes:** A sensor probe is any instrument or device that measures some physical or chemical characteristics of the environment and transmits the results as an electrical signal to the main automation computer for decision-making and control. Sensors installed on irrigation, misting, and fertiliser systems will monitor the performance of pumps and pressure lines, allowing the operator to stay informed about the system's efficiency. They can also be installed on vents, fans, and vented roofs to notify the operator if they stop working or operate outside of predefined parameters.

8. **Automated Irrigation System:** Irrigation is a necessary process for plant growth. Automation of the process could provide several advantages to growers in controlled environments. There are options to choose from, just as there are with any other type of automation. A fully computerised control system has all of the advantages of the simpler systems plus the ability to support a much wider range of input sensors, crop water use models, and, most importantly, efficient irrigation system capacity management.

9. **PH Meter**: This metre is used for analysing soil and water. It is critical to choose a fertiliser dose mix.

3.7 Advantages of High-tech Cultivation under Greenhouses

Comparing COFC, high-tech cultivation under greenhouses has several advantages. A few of them are listed below:

3.7.1 Land saving: Increased agricultural yields from GHs may result in better conservation of limited land resources. In 2008, the 3.3 million ha of greenhouse land in China produced the same volume of vegetables as would have required 7.7 million ha of CVC land (Chang et al., 2013). Alternatively, by reducing the need to convert species-rich natural ecosystems to farmland, the spared land could be used to provide other ecosystem services, such as protecting natural habitats and biodiversity (Fischer et al. 2008).

3.7.2 Nutrient Management: Hi-tech Horticulture is heavily reliant on the careful application of irrigation and nutrients to horticultural crops. Drip irrigation has resulted in increased yields and higher quality in fruits, vegetables, cut flowers, and plantation crops. Fertiliser schedules and leaf nutrient guides for a variety of horticultural crops have been developed. However, as biotechnology advances, so do planting practices and novel fertiliser application techniques. Planting at a high density (HDP) increases the plant population per unit area. It significantly increases crop yields. As a result, HDP is always recommended in conjunction with fertigation. Drip irrigation for fertilisation saves 30–50 percent of the water (Bhattacharyya et al., 2017).

3.7.3 Higher Production and Productivity:

Growers benefit from high-tech vegetable farming because of the improved quality, productivity, and market price. Many high-value vegetables, such as capsicum, cherry tomatoes, and tomatoes, are grown in polyhouses or net houses. Greenhouse tomato production has numerous advantages over field production, including careful monitoring of growing conditions and adequate maintenance techniques, which allow for year-round output in the off-season. In comparison to agricultural settings, greenhouses can offer a 15-fold increase in yield per acre. Furthermore, with greenhouse cultivation, more than 90 percent of the yields are marketable fruits, compared to 40–60 percent in open field production.

Figure 3.6

A: Conventional Tomato Cultivation **B: Greenhouse Tomato Cultivation**

Source: https://www.istockphoto.com/photos/tomato-greenhouse

3.7.4 Dealing with Climate Change: A greenhouse is a relatively self-contained, climate-controlled environment that allows crops to be grown throughout the year rather than just seasonally. Farmers can cultivate high-quality crops in harsh winter conditions or extreme summer heat if they have the right technologies to create the right climate inside the greenhouse.

3.7.5 Preventing Disease and Pests: Greenhouses can help prevent pest problems as well as provide better disease management. Only needed workers can enter and leave the enclosed room; therefore, the chance of bringing harmful factors close to the crops is reduced. It also enables the farmer to isolate issues if they arise. It is possible to save the remaining plants by moving diseased or infected plants away from the rest of the crop.

3.7.6 Aesthetic worth: Large, green landscapes have changed into vistas dominated by white, plastic-covered structures as a result of GVC's rising popularity, lessening these areas' aesthetic appeal. However, the various vegetables and fruits grown inside the greenhouses attract tourists and consumers for sightseeing and self-harvesting, respectively, potentially contributing to an emerging ecotourism industry. Plastic greenhouses also provide recreational opportunities for city dwellers while increasing farmers' economic benefits and social recognition (Chang et al., 2013).

3.8 Greenhouse Vegetable Cultivation in the World

Glass and plastic greenhouses are being used commercially in at least 89 countries throughout the world (Hickman 2010). The total area of greenhouses worldwide has increased from 0.7 million to 3.7 million hectares (ha) over the past two decades. China, Spain, South Korea, Japan, and Turkey are among the countries that use greenhouses extensively, accounting for 66.4 percent of global greenhouse coverage as of late 2010 (Sabir & Sing 2013). In 1999, plastic greenhouses accounted for 95 percent of the area covered by vegetable greenhouses in these countries, whereas glass greenhouses accounted for five percent (Enoch and Enoch 1999). Despite the fact that some European countries, such as the Netherlands and Italy, continue to rely significantly on glass greenhouses, the total development of vegetable production in Europe is on the rise. Although some European countries, such as the Netherlands and Italy, continue to rely heavily on glass greenhouses, the overall increase in vegetable greenhouse areas can be attributed largely to the increased use of plastic greenhouses for vegetable cultivation.

Table 3.1

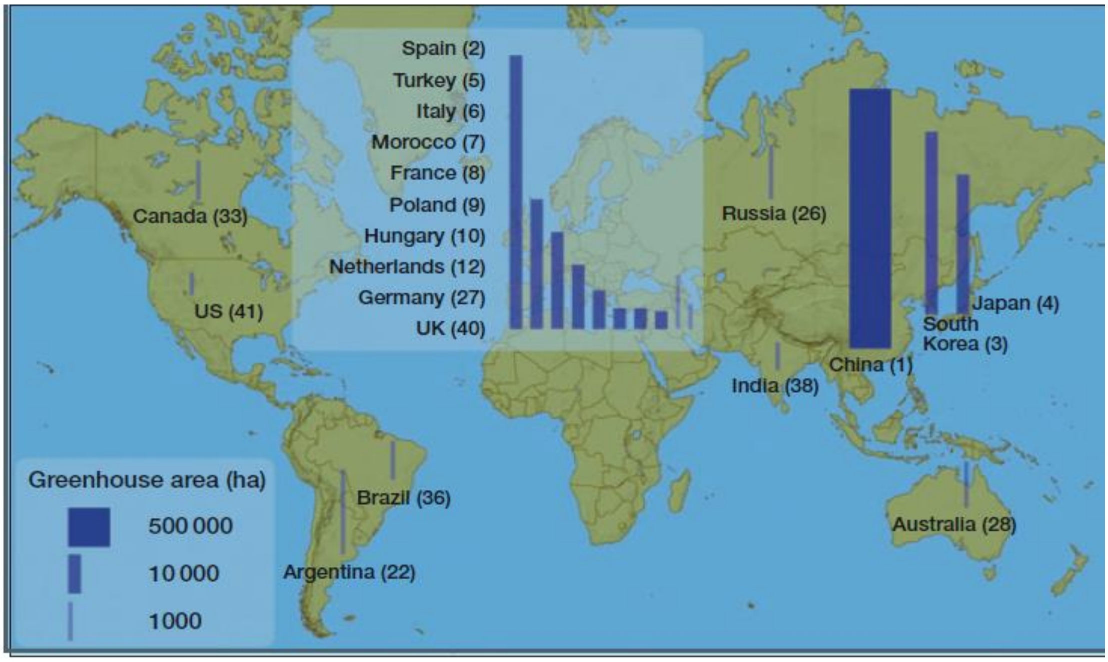
Major greenhouse vegetable production areas of the world (>500 ha only)

SL No	Country	Area ('000 ha)	*Percent	*Cumulative Percent	SL No	Country	Area ('000 ha)	*Percent	*Cumulative Percent
1	China	81	20.15	20.15	24	Chile	2.1	0.52	93.46
2	Spain	70.4	17.51	37.66	25	Jordan	2	0.50	93.96
3	South Korea	47	11.69	49.35	26	Belgium	1.6	0.40	94.35
4	Japan	36	8.96	58.31	27	Russia	1.4	0.35	94.70
5	Turkey	33.5	8.33	66.64	28	Germany	1.4	0.35	95.05
6	Italy	25	6.22	72.86	29	Australia	1.3	0.32	95.37
7	Morocco	16.5	4.10	76.97	30	Tunisia	1.3	0.32	95.70
8	France	10	2.49	79.45	31	Romania	1.3	0.32	96.02
9	Poland	5.2	1.29	80.75	32	Egypt	1.2	0.30	96.32
10	Hungary	5.4	1.34	82.09	33	Canada	1.2	0.30	96.62
11	Algeria	5	1.24	83.33	34	Bulgaria	1.1	0.27	96.89
12	Greece	5	1.24	84.58	35	Libya	1	0.25	97.14
13	Netherlan	4.6	1.14	85.72	36	Serbia/Mo	1	0.25	97.39
14	Columbia	1.2	0.30	86.02	37	Lebanon	1	0.25	97.64
15	Mexico	4.3	1.07	87.09	38	Brazil	1	0.25	97.89
16	Israel	4	1.00	88.08	39	UAE	0.8	0.20	98.08
17	Iran	4	1.00	89.08	40	India	0.7	0.17	98.26
18	Palestine	3.3	0.82	89.90	41	New Zealand	0.7	0.17	98.43
19	Syria	3.1	0.77	90.67	42	UK	0.7	0.17	98.61
20	Ukraine	2.7	0.67	91.34	43	USA	0.7	0.17	98.78
21	Ecuador	2.7	0.67	92.01	44	Moldova	0.5	0.12	98.91
22	Portugal	1.5	0.37	92.39	45	*Others	4.4	1.09	100.00
23	Argentina	2.2	0.55	92.94	Total		**402**	**100**	

Source: Sabir& Sing (2013); (Prakash et al., 2019)
Data are from Enoch and Enoch (1999) and Hickman (2010). *Author's estimation

Figure 3.7

Distribution of Major Greenhouse Cultivation Areas Worldwide in 2009



Numbers in parentheses indicate the rank, based on greenhouse area, of the different countries. *Data from Hickman (2010)*

3.9 Cultivation of Vegetable Crops in India

India produced 191.77 million metric tonnes of vegetables from an area of 10.35 million hectares in 2019–20, according to the National Horticulture Database (Second Advance Estimates) provided by the National Horticulture Board. According to the Food and Agriculture Organisation of the United Nations (FAO), India was the world's second-largest producer of fruits and vegetables in 2019. The quantity of vegetables produced in the country in 2018–19, 2019–20, and 2020–21 (Third Advance Estimates), as well as the average quantity produced in these three years, are as follows:

Table 3.2
Production of Vegetables

Year	2018-19	2019-20	2020-21	Average
(In Million Tonnes)	183.17	188.28	197.23	189.56

Source: Ministry of Agriculture & Farmers Welfare

The major vegetable-producing states in India include Uttar Pradesh, West Bengal, Madhya Pradesh, Bihar, Gujarat, Maharashtra, and Odisha (in order of production, as per the Third Advance Estimates of 2020–21). Currently, India produces 166.61 million MT of total vegetable production; however, most vegetable crops have low productivity and quality (17.41 t/ha) due to biotic and abiotic stressors in open-field farming (Choudhary & Verma, 2018). Since 2014–15, a centrally sponsored scheme called the Mission for Integrated Development of Horticulture (MIDH) has been in place. Activities such as the production of planting material, vegetable seed production, the coverage of areas with improved cultivars, the rejuvenation of senile orchards, protected cultivation, the creation of water resources, the adoption of Integrated Pest Management (IPM), Integrated Nutrient Management (INM), organic farming, and the adoption of IPM, INM, and organic farming are taken up for the development of fruits and vegetables under the MIDH. Farmers and technicians might also benefit from capacity training to help them adopt new technologies (*Production of Fruits and Vegetables*, 2021).

3.10 Greenhouse Vegetable Cultivation in India

Hi-tech cultivation has become a necessity in the new era of changing climates in order to sustain the productivity and economic stability of Indian farmers. Hi-tech horticulture is beneficial for the production of fruits, vegetables, and flowers. Hi-tech cultivation of horticultural crops is popular in most Indian states. Fully automatic polyhouses are among the different protected buildings that aid growth even in adverse climatic conditions. However, they are only cost-effective and commercially viable in a few places in India. Net houses and low poly-tunnels, which are both cost-effective structures, are becoming increasingly popular. In India, the area under protected cultivation was approximately 25000 ha, while the area under greenhouse vegetable cultivation was approximately 2000 ha (Sabir & Sing, 2013; Prakash et al., 2019).

3.10.1 Subsidy for Greenhouse cultivation in India

Following, we are showing a pattern of greenhouse subsidies in India.

A. The National Horticulture Board (NHB) provides a 50% subsidy subject to a maximum project ceiling of 112 lakh per beneficiary.

B. In Gujarat, GAIC (Gujarat Agro Industries Corporation) offers a 6% interest on loan subsidies subject to a maximum of Rs. 4 lakhs for greenhouse farming.

C. The NHM (National Horticulture Mission) offers a 50% subsidy subject to a maximum of 50 lakhs.

D. Further, each State Horticulture Mission (SHM) contributes an additional 15–25 percent on top of the NHM's 50 percent subsidy (*Greenhouse Farming States, Crops, Subsidy and Types in India*, 2022).

High-tech vegetable farming has a yield and income advantage over conventional farming. The following table illustrates the comparative advantage of this system over the traditional system as estimated by DEE, Tamil Nadu Agricultural University.

Table 3.3

Comparative statement of cost, yield and net income from horticultural crops grown conventionally and using hi-tech practices

SL No	Crops	Cost of Cultivation Rs /ha		Yield T/ha		Percent Yield increase over conventional	Net Income Rs /ha		*Net Income increase over Conventional
		Conventional	Hi-tech	Conventional	Hi-tech		Conventional	Hi-tech	
1	Tomato	61000	99800	50	150	200	39000	275200	605
2	Chilli	46000	68000	22	35	59	64000	142000	121
3	Paprika	49000	72000	37	60	62	136000	288000	111
4	Capsicum	49000	72000	18	25	39	95000	153000	61
5	Brinjal	50000	82000	60	150	150	70000	293000	318
6	Bhendi	40600	62000	10	16	60	19400	50000	157
7	Cabbage	51500	78000	75	110	46	173500	252000	45
8	Cauliflower	51500	78000	32000 flowers	44444 flowers	39	108500	1442000	1229
9	Tapioca	30000	49000	30	45	50	54000	140000	159
10	Watermelon	50000	72000	40	60	50	50000	108000	116
11	Musk melon	56000	76000	22	34	55	54000	128000	137
12	Ribbed gourd	42000	74000	20	30	50	38000	76000	100
13	Bottle gourd	42000	74000	40	66	65	78000	157000	101
14	Gherkins	48000	72000	20	35	43	72000	208000	188
15	Turmeric	45000	70000	5	8	38	55000	90000	63
16	Coriander	32000	48000	87000 bundle	125000 bundle	44	55000	77000	40
17	Banana	56000	115000	75	110	47	319000	655000	105
18	Chrysanthemum	55000	78000	20	25	25	245000	297000	21
19	Golden rod	77000	97200	15000 bunch	25000 bunch	67	73000	177800	143

*Author's estimation

Source: www.agritech.tnau.ac.in; Indian Journal of Fertilisers (December 2017)

3.11 Challenges of Greenhouse Farming

Because plants are grown in a greenhouse under controlled climatic conditions, this has its own set of issues. One of the most pressing issues is guaranteeing nutrient availability while also safeguarding plants from mineral deficiencies such as boron, nitrogen, phosphorus, calcium, iron, and potassium. Plants, too, can be harmed by an excess of nutrients. To guarantee that the plants receive appropriate nourishment and grow properly, constant monitoring and soil testing are required. The primary cost of a greenhouse is the upkeep of the transparent films. The biofilm on the walls and roof must be wiped on a regular basis since dust collects on it and reduces light transmission. Every year, the greenhouse must be solarized. Mulching is used for solarization, and the interiors are fumigated. In greenhouse agriculture, biological insect control or the use of bug traps is required. Pipes and sprinklers in the irrigation system need to be cleaned often so that germs do not build up and cause plants to get sick (Polyhouse Farming Guide, 2018).

CHAPTER IV

THE EXTENT OF HIGH-TECH VEGETABLE FARMING IN KERALA

4.1 Introduction

The health of the people in any society is inextricably linked to the quantity and quality of their food. Everyone loves a variety of foods, but their content is one of the most important for health. Vegetables are food items that cannot be ignored. Its type and quantity are all important. Kerala's climate and soil structure are favourable for vegetable cultivation to some extent, but it is a fact that production does not meet the requirements of the state. This chapter deals with the extent, production, and productivity of vegetable cultivation in Kerala as well as the number, area, and growth of high-tech vegetable cultivation. The inability to cultivate throughout the year, which is the biggest constraint of open fields, prompted Kerala to experiment with high-tech farming methods. This method was started on a very limited basis on just four farms in the Thrissur district and later spread all over Kerala. Since its inception in 2009–10, the activity has seen significant growth in the number and area of farms in subsequent years. This project's growth and expansion have been looked at for each district, each year, and each size of farm.

4.2 Vegetable Production in Kerala: Present Scenario

Though it has several constraints, open-field cultivation is the traditional method of raising vegetables in Kerala. In this context, it would be beneficial to examine the current state of vegetable cultivation in Kerala. The data for the period from 1991–92 to 2020–21 has been analysed to illustrate the first part. Accordingly, the area and production of vegetable cultivation declined by almost half during this period. Productivity, however, has been rising and falling for some years but remains largely unchanged.

Table 4.1
Area, Production and Productivity of Vegetables in Kerala

SL No	Year	Area (000 Ha)	Production (000 MT)	Productivity (MT/Ha)
1	1991-92	202.1	3229.10	15.98
2	2001-02	114.3	2541.90	22.24
3	2005-06	164.7	3546.10	21.53
4	2009-10	151.55	3518.06	23.21
5	2010-11	149.5	3392.70	22.69
6	2011-12	149.1	3626.00	24.32
7	2012-13	146.1	3446.90	23.59
8	2013-14	147.69	3572.67	24.19
9	2014-15	142.29	1645.06	11.56
10	2015-16	144.99	2088.66	14.41
11	2016-17	137.5	1921.45	13.97
12	2017-18	157	2516.47	16.02
13	2018-19	82.17	1212.02	14.75
14	2019-20	96.31	1490.05	15.47
15	2020-21	102	1570.00	15.39

Source: EPWRF database & Economic Review- various issues, KSPB

Table 4.1 illustrates the total area, production, and productivity of vegetables in the state for three decades. During this period, ups and downs in area, production, and productivity can be seen. Vegetable cultivation, which had 202 hectares in the first year and had advanced in some years, had gradually decreased and had decreased by half by the last year. This trend can be observed in total production as well. Production was 3229 MT in the first year and halved in the last year. However, during the same period, the population of the state increased from 2.91 crore to 3.33 crore. This, of course, increased the dependence on other states for essential vegetables. In terms of productivity, despite some short-term gains, the last year appears to have been nearly identical to the first. Kerala produces 4301.4 MT of vegetables per day, while its daily requirement is 5479 MT. Domestic production meets only 78 percent of demand. However, adults in India are advised to consume 275 grammes of vegetables each day. If it is taken into consideration, the daily requirement of vegetables in the state is approximately 7500 MT, and subsequently, the shortage is 3200 MT. So, it can be seen that the state of Kerala produced enough to meet only 57 percent of its total demand. The remaining 43 percent is met by imports from neighbouring states.

As a solution to this, high-tech farming was started in Kerala in 2009–10 to end the dependence on vegetables containing pesticide residues from other states and enable year-round vegetable cultivation. Inspired by the success of this endeavour in countries like Israel, the Netherlands, and some states in India where adverse conditions prevail, a few units were set up commercially in Kerala as well, with the heavy financial aid of the state and central governments.

4.3 The Extent of High-tech Vegetable Farming in Kerala

In the first two years, a very limited number of units were set up in the Thrissur district, but in later years, it was extended to all the districts, and approximately 837 farmers were ready to cultivate vegetables in this manner. It is useful to examine the distribution of high-tech farms in different districts in terms of their number and total area over the years.

Table 4.2

Number and Area of High-Tech Vegetable Farms in Various Districts

SL No	District	Number of Farms	Percent	Area in sq. m	Percent
1	Thiruvananthapuram	89	10.63	47668.72	12.95
2	Kollam	32	3.82	20148.62	5.47
3	Pathanamthitta	27	3.23	12801.00	3.48
4	Kottayam	47	5.62	16533.22	4.49
5	Alappuzha	35	4.18	15821.56	4.30
6	Ernakulam	97	11.59	41775.31	11.35
7	Idukki	112	13.38	44050.96	11.97
8	Thrissur	71	8.48	23699.83	6.44
9	Palakkad	40	4.78	19658.00	5.34
10	Malappuram	61	7.29	24201.85	6.57
11	Kozhikode	48	5.73	16931.42	4.60
12	Wayanad	107	12.78	49290.04	13.39
13	Kannur	41	4.90	29937.35	8.13
14	Kasargode	30	3.58	5599.66	1.52
Total		**837**	**100**	**368117.55**	**100**

Source: Principal Agricultural Offices of Various Districts

According to table 4.2, the Idukki district had the highest number of high-tech farms (13.38%), followed by Wayanad (12.78%) and Ernakulam (11.59%). The lowest was in Pathanamthitta (3.23%), followed by Kasaragod (3.58%) and Kollam (3.82%). More than one-fourth of these were concentrated in the two hilly districts of Idukki and Wayanad. But there were some differences in terms of area. Wayanad district had the largest area (13.39%), followed by Thiruvananthapuram (12.95%) and Idukki (11.97%) districts. The lowest area was in the Kasaragod district (1.52%), followed by Pathanamthitta (3.48%) and Alappuzha (4.30%) districts. Half of the total area was concentrated in the four districts of Wayanad, Thiruvananthapuram, Idukki, and Ernakulam. The other half was spread over the remaining 10 districts. All these facts show that, though high-tech vegetable cultivation is present in all the districts, it is more concentrated in a few districts. In short, in the state of Kerala, till the year 2019–20, there were a total of 837 farmers cultivating vegetables in an area of 368117.5 sq. m. under a high-tech farming system.

4.4 Number of Farms Established in Different Years

By the year 2019-20, a decade has passed since the start of commercial high-tech vegetable cultivation in the state. The venture, which was started by only four farmers, saw steady growth in the early years but stagnated in later years. It is observed that a detailed study in this regard is appropriate.

Table 4.3

Number of Farms Established in Different Years

Year of Starting	Number of Farms	Percent	Growth Rate (%)
2009-10	4	0.48	--
2010-11	6	0.72	**50**
2011-12	33	3.94	**450**
2012-13	129	15.41	**290.91**
2013-14	237	28.32	**83.72**
2014-15	176	21.03	-25.74
2015-16	86	10.27	-51.14
2016-17	37	4.42	-56.98
2017-18	84	10.04	**127.03**
2018-19	40	4.78	-52.38
2019-20	5	0.68	-87.5
Total	**837**	**100**	

Source: Principal Agricultural Offices of Various Districts

As table 4.3 illustrates, a very small number of farmers started high-tech vegetable cultivation in 2009–10. The number of new entrants to the project increased every year, reaching 237 during the year 2013–14 and finally 837 by 2019–20. However, in the last year, only five farmers were ready to try this new method. About three-quarters of the total number of farmers came under this activity between 2012–13 and 2015–16. Another year that changed significantly was 2017–18 (10.04%). Except for the years mentioned, the total was only about 15 percent. Similarly, if looking at the growth rate, the venture achieved rapid growth (average annual growth of 118.65%) until 2013–14. But the subsequent years show negative growth. A symptom of revival could be seen in 2017–18 (growth of 127.03%). But that comeback could not be sustained. Negative growth continued in recent years too.

4.5 Expansion of High-tech Vegetable Cultivation in the State

The total area of the farm is as important as the number of farms. To figure out the ups and downs of this sector, it is important to look at the amount of land in the state that has been set aside for high-tech vegetable farming over the past ten years.

Table 4.4

Area of GH Farms Established in Different Years

Year of starting	Area in sq. meter	Annual Growth Rate
2009-10	616.51	--
2010-11	788.12	**27.84**
2011-12	22552.45	**2761.55**
2012-13	46924.27	**108.08**
2013-14	124336.6	**164.97**
2014-15	83812.41	-32.59
2015-16	41927.2	-49.97
2016-17	17323.34	-58.68
2017-18	14778.38	-14.69
2018-19	13543.84	-8.35
2019-20	1514.39	-88.82
Total	**368117.55**	

Source: Principal Agricultural Offices of Various Districts

Table 4.4 indicates the spread of high-tech farms to new areas each year from the beginning to the end of the entire period. For the first two years, cultivation was limited to a very small area. But in the years that followed, there was a huge leap forward. In 2013–14, it reached its peak (124336.6 sq. m). However, the rate of expansion seems to be steadily declining, as has been the case with the number of farms. In the last year, it dropped sharply to 1514.39 square meters. An examination of the annual growth rate during the analysis period reveals almost the same trend. The year 2011–12 saw a huge jump compared to the previous year. It should be noted, however, that this was not sustained later and that a negative growth rate has occurred since the year 2014–15.

As the area of cultivation was not normally distributed, the Kruskal-Wallis Test is used to assess the equality of the mean rank of the area of cultivation per sq. m. in different years.

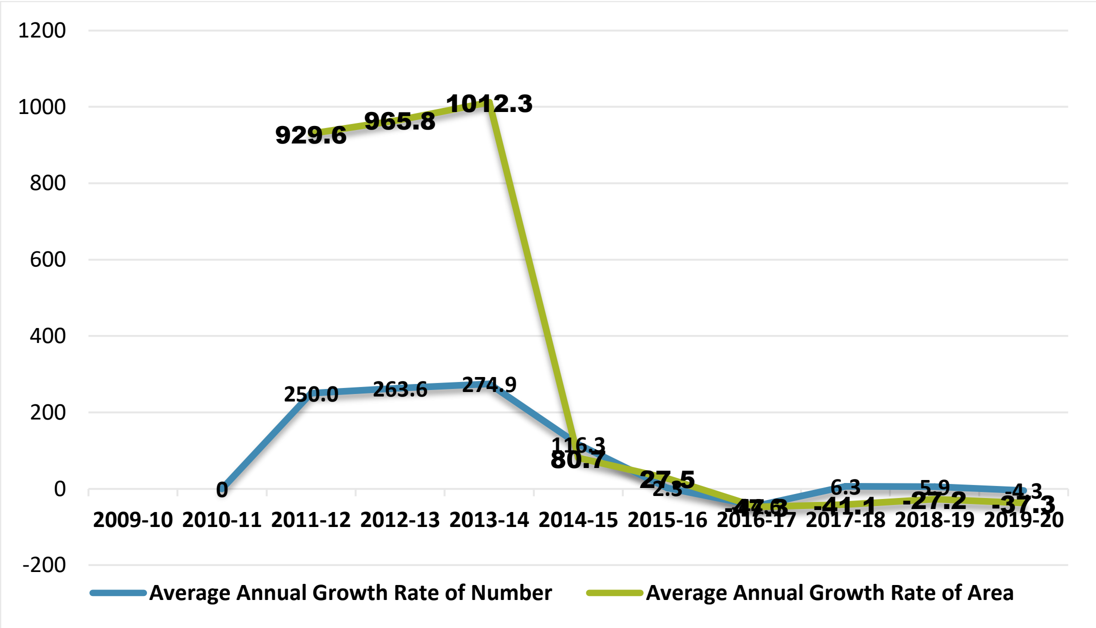
4.6 Growth in Number and Area of Farms: A Comparison

There is usually a close relationship between the number of farms and their total area. The reason for this is that as new farms are brought into this new trend of farming, the area of the farm will increase proportionately. But it would be appropriate to analyse whether such a relationship exists here.

Figure 4.1

Average Annual Growth Rate of Number and Area of GH Farms

(3 Period Moving Average)



Source: Principal Agricultural Offices of Various Districts

Figure 4.1 shows the growth trend (3-year moving average) of the number of farms and areas for cultivating vegetables in a high-tech manner. The venture, which initially achieved high growth rates both in number and area, failed to sustain itself later. The growth rate shows almost the same trend regardless of the number and area of the farms. However, the largest increase was in area growth rather than the number of farms until 2013–14. Since then, both have declined rapidly and eventually merged into negative growth rates. Growth stagnation in recent years is evident. The reluctance of farmers towards this venture in recent times needs to be further studied. It is discussed in later chapters.

4.7 Size-wise Distribution of High-tech Farms

There is a huge difference in the size of high-tech vegetable farms in Kerala. Let us go to a brief analysis of it.

Table 4.5

Size Description of High-tech Farms

	Number of Farms	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
					Statistic	Statistic	Std. Error	Statistic	Std. Error
Area sq. m.	837	10.00	4000	441.0365	437.6144	3.716	0.085	21.012	.169

Source: Author's Estimation

Table 4.5 provides statistical data pertaining to the area encompassed by high-tech farms, comprising a total of 837 farms. The dataset covers essential metrics such as the lower and upper bounds of farm areas (ranging from 10.00 to 4000 sq. m.), the mean size (441.04 sq. m.), and the variability of sizes around the average (shown by a standard deviation of 437.61 sq. m.). The distribution of farm sizes exhibits positive skewness, as evidenced by a skewness coefficient of 3.716. This suggests the presence of a small number of larger farms that extend beyond the right tail of the distribution. The distribution also demonstrates a somewhat greater degree of kurtosis (21.012) compared to a normal distribution, indicating the presence of variability and probable outliers. The aforementioned statistics jointly depict the diversity and attributes of high-tech farm sizes within the dataset.

Table 4.5.1

Size-wise Distribution of Farms

SL No	Size Category	Number of Farms	Percent	Total Area sq. m	Area Percent
1	Very small (Up to 100 sq. m.)	170	20.31	7567.19	2.06
2	Small (101-300 sq. m.)	62	7.41	11736.59	3.19
3	Medium (301-500 sq. m.)	442	52.80	178490.73	48.49
4	Large (501-1000 sq. m.)	118	14.09	91478.97	24.85
5	Very Large (Above 1000 sq. m.)	45	5.37	78844.06	21.42
Total		**837**	**100.00**	**368117.55**	100.00

Source: Principal Agricultural Offices of Various Districts

As table 4.5.1 shows, more than half (52.8%) of the total farms were of medium size. The next major category was very small units with an area of less than 100 sq. m. (20.31%), followed by large farms (14.09%), small (7.41%), and very large ones (5.37%). The product from very small units was mainly used for self-consumption, and no marketable surplus was found from them. It needs to be analysed whether the distribution of different-sized farms spread across different districts was the same. It is evident from table 4.6 that the distribution is not normally distributed. Therefore, the non-parametric test is used to determine the equality of average farm size among different districts.

Table 4.6

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	**df**	**p**	**Statistic**	**df**	**p**
Area sq.m.	.270	837	.000	.649	837	.000
a. Lilliefors Significance Correction						

Table 4.7

Size of Farm: Variation across Different Districts

District	N	Mean Rank of Area	Test Statistics[a,b]
Thiruvananthapuram	89	448.67	$\chi 2$ (13) = 55.895 p < 0.001
Kollam	32	523.61	
Pathanamthitta	27	489.52	
Kottayam	47	351.03	
Alappuzha	35	464.31	
Ernakulam	97	407.66	
Idukki	112	407.65	
Thrissur	71	344.94	
Palakkad	40	503.28	
Malappuram	61	407.01	
Kozhikode	48	396.5	
Wayanad	107	421.23	
Kannur	41	536.88	
Kasargode	30	242.8	
Total	837		

Source: Principal Agricultural Offices of Various Districts
a. Kruskal Wallis Test. b. Grouping Variable: Districts

As the actual level of significance of the test is zero, the hypothesis for the equality of average farm size across various districts is rejected. Then, as per table 4.7, large farms were mainly located in the Kannur district, followed by Kollam and Palakkad, with mean rank values of 536.88, 523.61, and 503.28, respectively. Small farms were more concentrated in the Kasargode district, followed by Thrissur and Kottayam with mean rank values of 242.8, 344.94, and 351.03 respectively.

Table 4.8

Size of Farm: Variation across the Year of Establishment Kruskal-Wallis Test

	Year of Establishment	N	Mean Rank	Test Statistics[a,b]
Area sq.m.	2009-10	4	191.75	**$\chi 2$ (10) = 128.264** **p < 0.001**
	2010-11	6	167.83	
	2011-12	33	546.91	
	2012-13	129	390.24	
	2013-14	237	449.85	
	2014-15	176	483.4	
	2015-16	86	481.87	
	2016-17	37	443.3	
	2017-18	84	198.86	
	2018-19	40	320.54	
	2019-20	5	295.8	
	Total	837		

Source: Principal Agricultural Offices of Various Districts

a. Kruskal Wallis Test. b. Grouping Variable: Year of Establishment

As the actual level of significance of the test is zero, the hypothesis for the equality of average farm size across the various years of establishment is rejected. Then, as per table 4.8, the size of farms established in 2011–12 is larger, followed by 2014–15 and 2015–16, as the mean rank values are 546.91, 483.4, and 481.87, respectively. Farms established in 2010–11 are smaller than those established in 2009–10 and 2017–18, as their mean rank values are 167.83, 191.75, and 198.86, respectively.

4.8 Government Subsidy for the Promotion of High-tech Farming

Hi-tech farming is much more expensive than open-field farming. The main reason for this is the high cost of setting up greenhouses. Therefore, farmers are generally reluctant to try this new method, even though it has the advantages of being able to control the climate, prevent insect attacks, or cultivate throughout the year. In this situation, various countries are providing huge financial assistance to attract farmers to this new farming method. In our country, the central and state governments are providing huge financial assistance for the promotion of this activity. Various schemes provide farmers with up to 75 percent of the standardised construction cost. The tables and figures that are then analysed show the amount of subsidy given to this venture in Kerala in different districts and over time.

Table 4.9

District-wise Difference in the Provision of Subsidy

SL No	District	Number of Farms	Percent	Amount of Subsidy Given (Rs)	Percent
1	Thiruvananthapuram	89	10.63	34369927	**13.02**
2	Kollam	32	3.82	14122820	**5.35**
3	Pathanamthitta	27	3.23	9714388	**3.68**
4	Kottayam	47	5.62	12037394	4.56
5	Alappuzha	35	4.18	11430245	**4.33**
6	Ernakulam	97	11.59	30410258	11.52
7	Idukki	112	13.38	30172678	11.43
8	Thrissur	71	8.48	14228411	5.39
9	Palakkad	40	4.78	13858842	**5.25**
10	Malappuram	61	7.29	16973781	6.43
11	Kozhikode	48	5.73	13172499	4.98
12	Wayanad	107	12.78	38540779	**14.60**
13	Kannur	41	4.90	21276622	**8.06**
14	Kasargode	30	3.58	3669293	1.39
Total		**837**	**100**	**26,39,77,937**	**100**

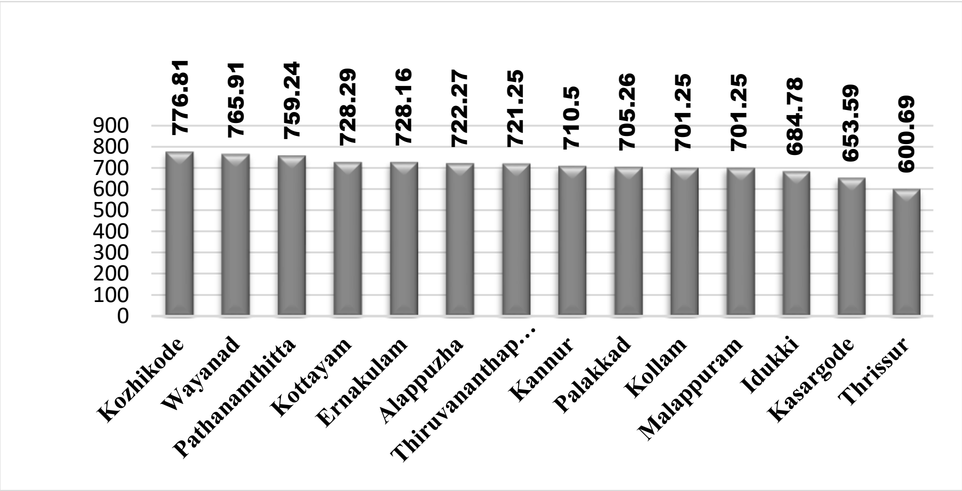
Source: Principal Agricultural Offices of Various Districts

As per table 4.9, a total of Rs. 26,39,77,937 has been disbursed in various districts during the last eleven years. Wayanad district, which has the second-highest number of farms, secured the largest amount, followed by Thiruvananthapuram, Ernakulam, and Idukki districts. Idukki district ranks first in the number of farms and fourth in receiving subsidies. This is because there are more small farms in the district. The lowest amount of subsidy was spent in the Kasaragod district, followed by Pathanamthitta. The last column of the table indicates the percentage of subsidies received by each district. It can be seen that the bold or normal digits are given by comparing it with the percentage of total farms in each district. The normal digit indicates a lower proportion of the subsidy relative to the number of farms. Instead, bold digit means that the number of subsidies is higher than the number of farms.

In addition, an examination of the average amount of subsidy given per square metre of cultivation will help to determine the difference between the districts in this regard. Figure 4.2 demonstrates that the Kozhikode district received the highest subsidy (Rs. 776), then Wayanad (Rs. 765) and Pathanamthitta (Rs. 759). Thrissur district received the lowest subsidy (Rs. 600), then Kasaragod (Rs. 653) and Idukki (Rs. 684) districts. In this regard, the difference between the highest-subsidised Kozhikode and the lowest-subsidised Thrissur was about Rs. 176. There are only minor differences between the other districts, which are not specifically mentioned.

Figure 4.2

Subsidy (per sq. m.) in Various Districts



Source: Principal Agricultural Offices of Various Districts

Table 4.10

Provision of Subsidy for Farms Established in Different Years

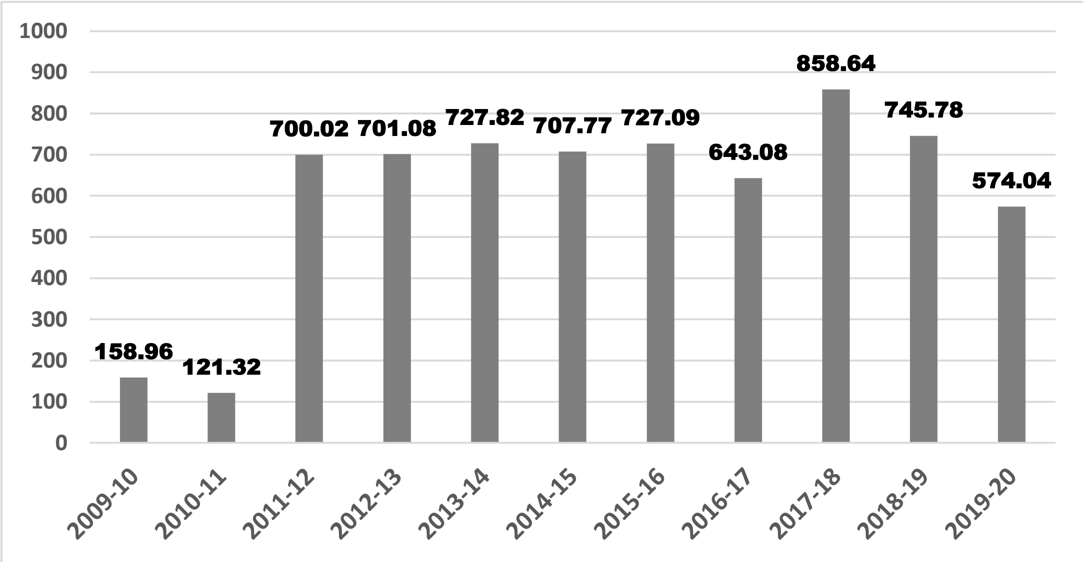
Year of Starting	Number of Farms	Percent	Subsidy Given (Rs)	Percent
2009-10	4	0.48	98001	0.04
2010-11	6	0.72	95612	0.04
2011-12	33	3.94	15787246	5.98
2012-13	129	15.41	32897807	12.46
2013-14	237	28.32	90494873	34.28
2014-15	176	21.03	59320067	22.47
2015-16	86	10.27	30484649	11.55
2016-17	37	4.42	11140371	4.22
2017-18	84	10.04	12689264	4.81
2018-19	40	4.78	10100726	3.83
2019-20	5	0.68	869321	0.33
Total	**837**	**100**	**26,39,77,937**	**100**

Source: Principal Agricultural Offices of Various Districts

According to table 3.10, 75 percent of total farms were established, and more than 80 percent of subsidies were paid only during the four years between 2012–13 and 2015–16. This indicates that the major contribution of farmers' entry into high-tech vegetable cultivation in the state occurred during this period. The last column of the table indicates the percentage of subsidies received by farmers each year. It can be seen that the highest proportion of subsidy was distributed in the year 2013-14 followed by 2014–15. On the other hand, the lowest proportion of subsidy was disbursed in the years 2009-10 and 2010-11 followed by 2019–20. The sector has expanded since 2012–13 with huge financial support from the government. But this speed could not be maintained later. It can be seen that by the year 2016–17, the sector had started facing a downturn. It can also be seen in the distribution of subsidies.

Figure: 4.3

Subsidy per sq. m in Different Years



Source: Principal Agricultural Offices of Various Districts

Initially, the government provided very little financial support for the project. But then it increased tremendously. Diagram 4.3 shows the average subsidy given for cultivation per square metre area for the period from 2009–10 to 2019–20. The subsidy, which was just Rs 158 in the first year, was reduced to Rs 121 the following year. It should be noted that the number and area of farms were very limited during this period. However, by the year 2011–12, the subsidy level had quadrupled to Rs. 700 as compared to the initial period. This level was sustained with little fluctuation until 2015–16. During the same period, high-tech vegetable cultivation expanded extensively in the state in terms of both number and area. Although the subsidy level peaked at Rs 856 in 2018–19, it continued to decline for the next two years. At the same time, it can be noted that the number and area of newly started farms are declining. In short, it can be seen that the government subsidy is essential for the expansion of high-tech agriculture.

Table 4.11

Distribution of Subsidy among Various Sizes of Farms

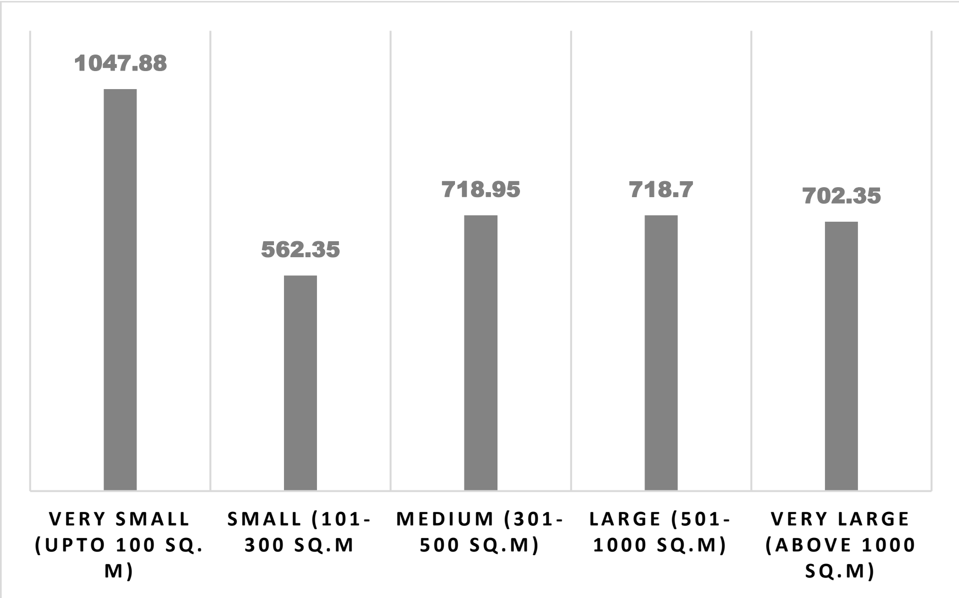
SL No	Size Category	Number of Farms	Percent	Total Subsidy in Rs.	Percent of Subsidy
1	Very small (Up to 100 sq. m.)	170	20.31	7929497.0	3.00
2	Small (101-300 sq. m.)	62	7.41	6600067.0	2.50
3	Medium (301-500 sq. m.)	442	52.80	128326086.0	48.61
4	Large (501-1000 sq. m.)	118	14.09	65745786.0	24.91
5	Very Large (Above 1000 sq. m.)	45	5.37	55376501.0	20.98
Total		**837**	**100**	**26,39,77,937**	**100**

Source: Principal Agricultural Offices of Various Districts

Table 4.11 indicates how the subsidy was distributed among farms of different sizes. Accordingly, the smallest section, which accounts for more than 20 percent of the total farms, received only 3 percent of the total subsidy. But for small (7.41%) and medium (52.8%) farms, it is 2.5 and 48.61 percent, respectively. On the other hand, in the cases of large farms (14.09%) and very large farms (5.37%), it is 24.91 percent and 20.98 percent, respectively. In short, about 46 percent of the total subsidy is spent on large and very large farms, which make up only 20 percent of the total farms. On the other hand, only 54 percent of the total subsidy has been spent on very small, small, and medium farms, which account for more than 80 percent of the total farms. This difference does not have much meaning, as the subsidy is given to some extent depending on the area of the farm. To know the depth, it is necessary to examine the rate at which the area per square metre is given.

Figure 4.4

Subsidy per sq. m. among Various Size Categories of GHs



Source: Principal Agricultural Offices of Various Districts

Figure 4.4 specifies the subsidy per square metre on farms of various sizes. Accordingly, the highest amount of subsidy is given to very small units. The lowest amount of subsidy is for small units, and approximately the same level of subsidy is available for the other three categories, such as medium, large, and very large.

The correlation between farm size and subsidies is given in table 4.12. Even though they are small, there is a significant negative correlation between farm size and the subsidy per sq. m. given to them.

The reason for the large subsidy scale in the very small units is that several units with 10, 20, and 40 sq. m. of area for producing vegetables for household consumption have been started in different districts as part of the government's Vegetable Development Programme (VDP). The level of subsidies in that programme was relatively high.

Table 4.12

Correlation Between GH Size and Subsidy

			Size Category	**Rank of Subsidy_sq. m.**
Spearman's rho	Size Category	Correlation Coefficient	1.000	-0.074*
		p (2-tailed)	.	.031
		N	837	837
	Rank of Subsidy_sq. m.	Correlation Coefficient	-.074*	1.000
		p (2-tailed)	.031	.
		N	837	837
*. Correlation is significant at the 0.05 level (2-tailed).				

4.9 Conclusion

High-tech farming in greenhouses has a lot of potential in the state as a new method of production. In the Thrissur district, the first attempt in this direction was made in the financial year 2009–2010. The endeavour thereafter made significant progress and grew rapidly up until the years 2013–2014. Except for the year 2017–18, there was a slowdown in the growth of new units following that. All of the state's districts practiced high-tech vegetable cultivation, but some, such as Idukki, Wayanad, Ernakulam, and Thiruvananthapuram, dominated. However, the districts of Pathanamthitta, Kasargode, and Kollam had the fewest farms. Even though the government generously subsidised this venture, it has no influence over the state's vegetable production. It was limited to around 37 hectares, only occupying a negligible portion of the total area of vegetable cultivation in the state.

CHAPTER V

SOCIO-ECONOMIC CHARACTERISTICS OF HIGH-TECH FARMERS AND THEIR INFLUENCE ON PRODUCTION AND PRODUCTIVITY

5.1 Introduction

This chapter conducts a thorough investigation into the socio-economic characteristics of high-tech farmers as well as an in-depth investigation into the distinct characteristics of greenhouses and their consequential effects on agricultural production and productivity. The chapter is divided into two sections: the first is devoted to a detailed examination of these multidimensional qualities, followed by an in-depth consideration of their far-reaching implications.

The research depends on a comprehensive collection of original data sets, rigorously collected and selected for the purpose of this study, to reveal insights into these complicated dynamics. The dataset was compiled from a diversified sample of 165 greenhouse vegetable farmers from Kerala. This sampling strategy ensures that farmers of various sizes and characteristics are included, contributing to a rigorous and complete analysis.

The socioeconomic characteristics of high-tech farmers are essential to the inquiry. This component includes a variety of elements such as educational backgrounds, financial standing, technological competency, and innovative adoption practices. The research intends to identify patterns and trends that will provide significant insights into the social and economic environment of contemporary agricultural practices by analysing these components.

Concurrently, the study thoroughly investigates the distinguishing features of greenhouses and technologically advanced infrastructures that have revolutionised modern farming. These greenhouses' design, size, automation levels, and climatic control methods are thoroughly examined. This investigation extends to assessing the impact of these variables on overall output and, as a result, greenhouse vegetable farming productivity.

Through a complex mix of data analysis, statistical approaches, and interpretive methods, this chapter gives a full picture of how socioeconomic variables, greenhouse characteristics, and agricultural productivity interact with each other. The combination of multiple data sources and analytical methodologies strengthens the findings' reliability and robustness, enhancing our understanding of the emerging landscape of high-tech farming practices in Kerala.

5.2 Demography of Respondents

The farmers on whom the information has been collected were of a very wide variety. Their social and economic backgrounds were different. There was also a large difference in the size of the greenhouse, other features, and the facilities used. A description of their social circumstances is given.

5.2.1 Social Characteristics of Respondents

Table 5.1 illustrates that 98.78 percent of the total farmers were individuals, and only 1.2 percent were institutions. With the exception of a few cooperatives, this farming method is dominated by individuals. The male participation rate was 81.2 percent, while the female participation rate was 17.6 percent. It can be seen that the participation of men in greenhouse farming was many times higher than that of women. The fact that farming is a rural activity is also true of greenhouse farming. 83 percent of the total farmers were from rural areas. Only the remaining 17 percent were from urban areas. Out of the assessment of the educational status of high-tech farmers, 38.2 percent have a bachelor's degree, 7.9 percent have a postgraduate or professional degree, 37 percent have intermediate qualifications, and the remaining 17 percent have SSLC qualifications. The level of education can be seen to be relatively high among these farmers.

Table 5.1

Social Characteristics of Respondents

Characteristics	Number	Proportion
Individual/Institution		
Individual	163	98.78%
Institution	2	1.2%
Total	165	100%
Gender		
Male	134	81.2%
Female	29	17.6%
Institution	2	1.2%
Total	165	100%
Location		
Rural	137	83%
Urban	28	17%
Total	165	100%
Education		
Up to SSLC	28	17%
PDC/ Plus Two	61	37%
Graduation	63	38.2%
PG/ Professional Edn.	13	7.9%
Total	165	100%
Age		
Up to 40 Years	9	5.5%
41-55 Years	75	45.5%
56-70 Years	62	37.6%
Above 70 Years	19	11.5%
Total	165	100%
Religion		
Hindu	76	46.06%
Christian	74	44.84%
Muslim	13	7.87%
No Religion	2	1.2%
Total	165	100%
Caste		
General	137	83.03%
OBC	26	15.7%
SC	0	0%
ST	0	0%
Others (Institution)	2	1.2%
Total	165	100%

Source: Primary Data

Considering their age, the vast majority of farmers were middle-aged or older. 45.5 percent were between the ages of 41 and 55, and 37.6 percent were between the ages of 56 and 70. 11.5 percent were over 70 years of age, while only 5.5 percent were under 40. Although more than half of the population of Kerala is Hindu, the share of greenhouse agriculture is only 46.06 percent. Similarly, Muslims, who make up the state's second-largest population, own only 7.87 percent of greenhouse farms. On the other hand, the Christian community, which is the third-largest population, has 44.84 percent representation in this venture. The reason for this high participation may be that they are generally ready for new experiments in the field of agriculture. About 1.2 percent of non-religious people also use this system of farming. Furthermore, 83.03 percent of greenhouse farmers belonged to the general (forward) caste, and 15.7 percent belonged to the OBCs. No participation was found in the SC and ST communities. In other words, people from forward castes dominate the greenhouse vegetable farming activity in the state.

5.2.2 Economic Characteristics of Respondents

Table 5.2 clarifies the economic circumstances of the respondents**.** Just 15.8 percent of farmers use greenhouse farming as a full-time activity. For the remaining 84.2 percent, it was a part-time endeavour in addition to other activities. The main economic activities of part-time greenhouse growers included business (28%), open-field farming (28.5%), self-employment (6.7%), profession (4.8%), and government or semi-government employment (3%). Moreover, 12.1 percent were retired from various services. Out of the total land ownership of the respondents, 71.5 percent had less than one hectare (ha) of land. Smallholders with one to two ha accounted for 17 percent, semi-medium farmers with two to four ha accounted for 7.3 percent, farmers with 4 to 10 ha accounted for 3.6 percent, and large landowners with more than 10 ha accounted for only 0.6 percent. The need for training is high as greenhouse farming is a highly technology-based activity. 89.1 percent of the farmers were trained in this activity. But the remaining 10 percent received no training.

Table 5.2

Economic Characteristics of Respondents

Characteristics	Number	Proportion
Nature of Activity		
Full time	26	15.8%
Part-time	139	84.2%
Total	165	100%
Major Occupation		
Hi-tech farming	26	15.8%
Govt/Semi Govt.	5	3%
Business	48	29%
Profession	8	4.8%
Self Employed	11	6.7%
Retired Person	20	12.1%
Open Filed Cultivation	47	28.5%
Total	165	100%
Land Holding		
Marginal (Less than 1 ha)	118	71.5%
Small (1- 2 ha)	28	17%
Semi-Medium (2- 4 ha)	12	7.3%
Medium (4-10 ha)	6	3.6%
Large (Above 10 ha)	1	0.6%
Total	165	100%
Training		
Trained	147	89.1%
Not Trained	18	10.9%
Total	165	100%

Source: Primary Data

5.3 Characteristics of Greenhouses

Greenhouses are not all the same. They differ in size, roof shape, cultivation method, ventilation arrangement, existence, and direction. Table 5.3 describes various features of greenhouses used for vegetable cultivation in Kerala. Greenhouses were divided into five categories according to size. The smallest, measuring up to 100 sq. m., accounted for 11.5 percent of the total. The medium size of 301 to 500 sq. m accounted for 53.93 percent, while the large size of 501 to 1000 sq. m accounted for 18.18 percent. The small houses with a size of 101 to 300 sq. m. and the very large farms with a size of over 1000 sq. m. were 6.66 percent and 9.69 percent, respectively.

Table 5.3
Characteristics of Greenhouses

Characteristics	Number	Proportion
Size of Greenhouses		
Very Small (Up to 100 sq. m)	19	11.5%
Small (101 - 300 sq. m)	11	6.66%
Medium (301-500 sq. m)	89	53.93%
Large (501-1000 sq. m)	30	18.18%
Very Large (Above 1000 sq. m)	16	9.69%
Total	165	100%
Nature of Farming		
Organic	129	78.18%
Non- organic	36	21.8%
Total	165	100%
Type of Roof		
Gable Type	15	9.1%
Sawtooth Type	146	88.5%
Quonset	4	2.4%
Total	165	100%
Direction of Greenhouses		
North-south	47	28.5%
East-west Total	118 165	71.5% 100%
Covering		
Fully Covered	161	97.5%
Not Fully Covered	4	2.5%
Total	165	100%
Usage of Shade Net		
Shade net used	149	90.3%
Shade net not used	16	9.7%
Total	165	100%
Ventilation		
Naturally Ventilated	154	93.3%
Fan Ventilated	11	6.7%
Total	165	100%
Existence		
Lean-to other buildings	5	3.03%
Separate Existence	160	96.97%
Total	165	100%

Source: Primary Data

Cultivation in the greenhouse is possible both organically and non-organically. 78.18 percent of respondents used the organic method, while the remaining 21.8 percent used the non-organic method. The greenhouses were classified based on shape. In Kerala, the most common types were gable, sawtooth, and quonset. Sawtooth accounted for 88.5 percent of the total. Other forms included gable (9.1 percent) and quonset (2.4 percent). The degree of sunlight exposure depends to some extent on the direction of the greenhouses. About 71.5 percent of the respondents in the state have set up greenhouses in the east-west direction. The remaining 28.5 percent adopted a north-south direction. Greenhouses need to be covered with transparent sheet on all four sides, in addition to the roof, for proper yield. Rarely, however, it is cultivated with only a canopy. 97.5 percent of the respondents cultivated in fully covered greenhouses. Shade nets are essential in tropical greenhouses. They are used to regulate temperatures and can be retracted or folded depending on whether the temperature is high or low. It was used in 90.3 percent of the greenhouses. Two basic types of ventilation in greenhouses are natural ventilation and fan ventilation. Natural ventilation is provided by movable windows set into the wall near the roof of the greenhouse. Fan ventilation is the installation of electric fans to move the hot air outside. 93.3 percent of the sample greenhouses were naturally ventilated, and the remaining 6.7 percent were fan-ventilated. Greenhouses shall be sited leaning to a building or in open places. However, 96.97 percent of the sample greenhouses were sited in open places, and the remaining 3.03 percent were sited lean-to other buildings like houses.

5.4 High-tech Facilities Used in the Greenhouses

The key high-tech facilities utilised in greenhouse farming include foggers, small sling psychrometers, hygrometers, anemometers, CO2 monitors, fans and pads, sensors, automated heat control systems, automated irrigation, etc. Table 5.4 lists the major high-tech facilities used by greenhouse farmers in Kerala. Foggers (82.42%) and automated irrigation systems (97.57%) were the facilities widely used by them. Other facilities were only used infrequently. Fans, pads, sensors, and automatic heat control systems were used by only 3.03 percent, 0.6 percent, 1.8 percent, and 1.8 percent of respondents, respectively.

Table 5.4

High-tech Facilities Used in the Greenhouses

SL No	High-tech facility	Number of Farms	Proportion
1	Fan	5	3.03%
2	Cooling Pad	1	0.6%
3	Fogger	136	82.42%
4	Sensor	3	1.81%
5	Automated Heat Control System	3	1.81%
6	Automated Irrigation and Fertigation System	161	97.57%
7	Others	1	0.6%

Source: Primary Data

As table 5.4 shows, the number of high-tech facilities used by greenhouse vegetable growers in Kerala was very limited. Therefore, in Kerala, only the medium-tech greenhouse farming method is followed for vegetable cultivation.

5.5 Greenhouse Vegetable Production Among Various Socio-economic Categories

The participation of different socio-economic groups in greenhouse farming is different. These differences may affect, to some extent, the quantity of products they produce. This section looks at the difference between each socio-economic group's total production and its average production.

5.5.1 Annual Output Across Categories of Gender of Farmers

The participation, interest, time, and effort expended by women and men in different fields of production are all different. The differences between these categories in vegetable production in the greenhouses are given in table 5.5. Males outnumber females in total production, average production, low production, and high production. This difference may be due to the fact that women mostly cultivate in small greenhouses. Although very limited, this difference also exists in comparison to institutions.

Table 5.5

Difference in Annual Output of Vegetables across Categories of Gender of the Farmer

SL No	Category	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	Male	134	5529.57	740963	130	173000	15133.55
2	Female	29	4071.51	118074	79	12500	3266.54
3	Institution	2	3300.00	6600	0	6600	4666.90
Total		165	5246.28	865637	0	173000	13712.9

Source: Primary Data

Table 5.5.1
Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of gender of farmers	Independent Sample Kruskal-Wallis Test	0.904	Retain the null hypothesis

The significance level is 0.05

However, supplementary table 5.5.1 indicates that the difference in output between these categories was not statistically significant. As per the Kruskal-Wallis test result, the null hypothesis was retained.

5.5.2 Annual Output across Rural and Urban Greenhouses

Agriculture is mainly concentrated in rural areas. Most of the greenhouses are located in rural areas. But with high technology, vegetable cultivation is possible in urban areas as well, overcoming space constraints. About 17 percent of the total respondents were from urban areas. It was, therefore, advisable to examine whether there was a difference in production between greenhouses in rural and urban areas.

Table 5.6

Annual Output across the Location

SL No	Location	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	Rural	137	5274.86	722657	79	173000	14859.59
2	Urban	28	5106.42	142980	32	27000	5472.78
Total		165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.6.1

Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of location of the farms	Independent Sample Mann-Whitney U Test	0.342	Retain the null hypothesis

The significance level is 0.05

As table 5.6 illustrates, the annual total output and average output of rural greenhouses were 722657 kg and 5274.86 kg, respectively. The same figures for urban greenhouses were 142980 kg and 5106.42 kg, respectively. The difference was also observed in the figures for the minimum and maximum output of these two locations. However, as per table 5.6.1, the Mann-Whitney U test retained the hypothesis that the difference in annual output of rural and urban greenhouses was not statistically significant.

5.5.3 Annual Output across Educational Categories

The level of education of those participating can have a substantial impact on the level of production in a given activity. This is especially true where advanced technology is necessary, such as in greenhouse farming. Table 5.7 shows the annual production of farmers of different educational levels engaged in greenhouse vegetable cultivation.

Table 5.7

Annual Output across Educational Categories

SL No	Level of Education	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	Up to SSLC	28	4849.04	135773	32	15000	3702.85
2	PDC/Plus Two	61	3399.59	207375	140	14000	3245.26
3	Graduation	63	4653.79	293189	79	27000	4636.28
4	Post Gradu / Professional	13	17638.46	229300	370	173000	46791.61
Total		165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.7.1

Hypothesis Test Summary

	Null Hypothesis	Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of level of education	Independent Sample Kruskal-Wallis Test	0.096	Retain the null hypothesis

The significance level is 0.05

According to table 5.7, the average yearly output produced by postgraduate or professionally qualified farmers was higher than that of the other groups. In addition, their standard deviation was quite significant. The Kruskal-Wallis test, however, retained the hypothesis of no significant variation in the distribution of annual production across different educational groups, as shown in table 5.7.1.

5.5.4 Annual Output across Age Categories

Determining the rate of production in an area can have a significant impact on the age of those engaged in it. Younger people are more dynamic, while older people are more experienced. This can have a significant impact on production, especially in areas where greenhouse farming requires more attention and experience from farmers. Table 5.8 shows the yields of farmers of different ages engaged in greenhouse vegetable cultivation.

Table 5.8
Annual Output across Age Categories

SL No	Age Category	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	Up to 40 Years	9	5095.44	45859	32	13000	4705.94
2	41 to 55 Years	75	6294.67	472100	130	173000	19999.96
3	56 to 70 Years	62	4504.16	279258	140	16000	3652.780
4	Above 70 Years	19	3601.05	68420	300	8000	2107.953
Total		165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.8.1
Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of age	Independent Sample Kruskal-Wallis Test	0.563	Retain the null hypothesis

The significance level is 0.05

Table 5.8 shows the average, total, minimum, maximum, and standard deviation of output from greenhouse vegetable farmers of various ages. The average productivity of individuals aged 56 to 70 years was the lowest, while that of those aged 41 to 55 years was the highest. This difference, however, was not statistically significant, according to table 5.8.1. In determining output variation, the farmers' age difference was not a significant factor.

5.5.5 Annual Output across Religious Categories

What religion a person belongs to does not generally affect the productivity of the activity in which he works. However, religion plays an important role in the demographics of the state of Kerala. Religious factors may also influence the variability of traditional economic activities. The dominance of the Christian community in agriculture in general can be seen in the number of greenhouses, too.

But it remains to be seen whether this dominance has had a positive impact on the output of this sector.

Table 5.9

Annual Output across Religious Categories

SL No	Religious Category	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	Hindu	76	4569.87	347310	130	16000	3829.39
2	Christian	74	6415.34	474735	32	173000	20085.56
3	Muslim	13	2576.31	33492	79.00	6050.00	2150.92
4	No religion	2	5050.00	10100	3500	6600	2192.03
	Total	165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.9.1

Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of religion of the farmers	Independent Sample Kruskal-Wallis Test	0.293	Retain the null hypothesis

The significance level is 0.05

As seen in table 5.9, the average output was higher for the Christian community. It was followed by no religion and Hindus. The average yield of Muslim farmers was the lowest. This difference, however, is not substantial, according to table 5.9.1. To put it another way, religious differences have no role in the quantity of annual output produced by greenhouse vegetable farmers in the state.

5.5.6 Annual Output across Caste Categories

Although less important than in the past, caste distinction is still a reality in Kerala society. Education and urbanisation have greatly reduced its impact. But it would be good to evaluate the performance of different castes in greenhouse vegetable cultivation.

Table 5.10

Annual Output across Caste Categories

SL No	Caste Category	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	OBC	26	3492.38	90802	79	13000	3012.01
2	General	139	5574.35	774835	32	173000	14870.80
Total		165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.10.1

Hypothesis Test Summary

	Null Hypothesis	Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of caste of the farmers	Independent Sample Mann-Whitney U Test	0.421	Retain the null hypothesis

The significance level is 0.05

Table 5.10 showed that the average output of general category (forward caste) farmers was higher than that of OBCs. No SC or ST greenhouse farmers were found. Even though the difference in average output was visible, it was not statistically significant, as the Mann-Whitney U test retained the hypothesis of no significant difference in the distribution of annual output across caste categories (Table 5.10.1).

5.6 Annual Output across Full-time and Part-time Farmers

There are people who do greenhouse vegetable farming full-time and some who do it part-time while doing other things. The first group accounts for 15.8 percent of the total, while the second group accounts for 84.2 percent. Those who engage in it as a full-time activity are more likely to produce more than those who engage in it as a part-time activity. The table below shows how much the difference was.

Table 5.11

Annual Output across Full time and Part-time activity

SL No	Time Category	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	Full time	26	7220.5	187733	143	27000	6077.22
2	Part-time	139	4877.01	677904	32	173000	14693.87
Total		165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.11.1

Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of full-time and part-time farmers	Independent Sample Mann-Whitney U Test	0.003	Reject the null hypothesis

The significance level is 0.05

Table 5.11 shows that full-time farmers' average output was 7220.5, whereas part-time farmers' average output was 4877.01. Full-time farmers produced approximately 48 percent more than part-time farmers on an annual basis. The Mann-Whitney U test rejected the hypothesis that annual output was the same among full-time and part-time greenhouse farmers. Table 5.11.1 indicated that this difference was statistically significant.

5.7 Annual Output across Major Occupations

It was already mentioned that some people had turned greenhouse vegetable farming into a full-time job, while others did it part-time while working other jobs. Government and semi-government jobs, business, professions, self-employment, and traditional open-field farming were the main vocations of part-time farmers engaged in this activity. Aside from that, there were people who had retired from various jobs and were now enjoying their leisure time. The table below shows which segment produced the most and whether each segment's production variance was significant.

Table 5.12

Annual Output across Various Occupations

SL No	Occupation Category	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	Hi-tech Farming	26	7220.5	187733	143	27000	6077.22
2	Govt./Semi Govt	5	4315.8	21579	32	10000	4275.68
3	Business	48	6676.88	320490	140	173000	24668.13
4	Profession	8	4541.25	36330	160	16000	5132.79
5	Self-Employment	11	2447.27	26920	170	5300	1833.73
6	Open Field Farming	47	4778.62	224595	130	13000	3305.91
7	Retired Person	20	2399.5	47990	200	6300	1705.31
Total		165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.12.1

Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of occupation of the farmers	Independent Sample Kruskal-Wallis Test	0.004	Reject the null hypothesis

The significance level is 0.05

Table 5.12.2

Pair-wise Comparison

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sign
Retired Person-High tech Farming	48.098	14.203	3.387	0.001	0.015
Business-High tech Farming	35.986	11.628	3.096	0.002	0.041

Each node shows the sample average rank of Main Occupation of the Farmer

Table 5.12 shows that high-tech farmers, followed by businesspeople, open-field farmers, and professionals, had the highest average yearly output. The lowest average annual production was among retirees, then self-employed individuals, and those working for the government or semi-government. The null hypothesis of no difference was rejected in table 5.12.1, indicating that this difference was statistically significant. Table 5.12.2, on the other hand, shows a pairwise comparison of employment categories. As a result, the annual average output of high-tech farmers differed only slightly from that of retirees and businesspeople. There was no statistically significant difference between the other groups.

5.8 Annual Output across Total Land Holdings of Farmers

It was previously discovered that the greenhouse area where the veggies are cultivated is different. It is important to look at how greenhouse growers' overall land area varies and how it influences their greenhouse production. This requires an examination of the fact that some of the farmers whose data was collected included marginal landowners with a few cents to large owners with 50 acres of land.

Table 5.13

Annual Output across Various Land Holding Category

SL No	Landholding Category	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	Marginal (Below 1 ha)	118	5324.21	628257	32	173000	16076.61
2	Small (1- 2 ha)	28	5555.00	155540	200	13000	3983.1
3	Semi-Medium (2- 4 ha)	12	3997.50	47970	140	10500	2627.73
4	Medium (4-10 ha)	6	4945.00	29670	1420	10000	3784.46
5	Large (Above 10 ha)	1	4200.00	4200	4200	4200	---
Total		165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.13.1
Hypothesis Test Summary

	Null Hypothesis	Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of land holding by the farmers	Independent Sample Kruskal-Wallis Test	0.231	Retain the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

As shown in table 5.13, small landholders had the highest average yearly output, followed by marginal and medium landholders. Semi-medium landowners had the lowest average output, followed by large landowners. These disparities in average annual output, however, were not substantial, as shown in table 5.13.1. As a result, the hypothesis that the annual output distribution is the same across land-holing categories was kept.

5.9 Annual Output across Duration of Training to Farmers

The high-tech farming method requires a lot of technical knowledge. Therefore, only those who are adequately trained can succeed in it. A number of training programmes have been organised under the auspices of the Kerala Agricultural University. The table below shows that the production rate of those who have been trained for at least a week is higher than that of others.

Table 5.14

Annual Output across Training Category

SL No	Duration of Training	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	One week and more	89	6709.27	597125	32	173000	18292.38
2	Less than one week	76	3533.05	268512	79	15000	3614.43
Total		165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.14.1

Hypothesis Test Summary

	Null Hypothesis	Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of training duration	Independent Sample Mann-Whitney U Test	0.002	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

Table 5.14 shows that farmers who received at least one week of training had significantly greater average yearly output than those who did not receive training or received training for less than one week. The former's average output was 90 percent higher than the latter's. The difference is statistically significant, according to table 5.14.1. As a result, the hypothesis that the distribution of annual output is the same across training duration categories was rejected.

5.10 Annual Output across Types of Greenhouses

The characteristics of the greenhouse and the farming techniques have an impact on the output rate. Organic and non-organic growing methods are the two most common types. The roof, the direction and standing of the structure, the covering method, the usage of shade nets, and the type of ventilation are all features of the greenhouses.

5.10.1 Annual Output Difference across Organic and Nonorganic Farming

Only organic manure and pesticides are used in organic farming. Nonorganic farming, on the other hand, refers to the use of organic manure, organic insecticides, chemical fertilisers, and chemical pesticides as needed. Farmers in Kerala employ both of these approaches for greenhouse agriculture. However, as seen in the table below, this discrepancy has an impact on production.

Table 5.15

Annual Output across Organic and Nonorganic Farming

SL No	Method of Cultivation	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	Organic	129	4037.81	520878	32	27000	3882.88
2	Nonorganic	36	9576.64	344759	79	173000	28307.44
Total		165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.15.1
Hypothesis Test Summary

	Null Hypothesis	Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of method of cultivation	Independent Sample Mann-Whitney U Test	0.161	Retain the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

Nonorganic farms produced more average and total output than organic farms, according to table 5.15. Non-organic farms produced more than twice as much as organic farms. This difference, however, was not significant, as seen in table 5.15.1. The Mann-Whitney U test confirmed the hypothesis that the annual output distribution is the same across both cultivation methods.

5.10.2 Annual Output across Covering of Greenhouses

For vegetable cultivation, fully covered and non-covered greenhouses are used. The first category accounts for 97.5 percent of the total. It is possible to check the difference in annual production between these. The table below illustrates this point.

Table 5.16
Annual Output across Covering of Greenhouses

SL No	Covering of Greenhouses	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	Fully Covered	161	5369.70	864522	32	173000	13860.46
2	Not Fully Covered	4	278.75	1115	79	400	98.18
Total		165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.16.1

Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of covering of greenhouses	Independent Sample Mann-Whitney U Test	0.005	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

According to table 5.16, production in totally enclosed greenhouses appeared to be higher than in the others. The former category's average production was 5369.7 kg, while the latter category's average production was only 278.75 kg. In other words, on average, the first category produces 20 times more than the second. This discrepancy was significant, as seen in table 5.16.1. This meant that the greenhouses needed to be totally covered.

5.10.3 Annual Output across Usage of Shade Net in Greenhouses

Shade nets are an integral part of greenhouses in areas with high temperatures. It is used by most (90.3%) greenhouses from where information was collected. However, a small section (9.7%) of farmers did not use it. The table below shows the volume of production in greenhouses using and not using shade nets.

Table 5.17

Annual Output across Covering of Greenhouses

SL No	Usage of Shade Net	Number	Average Output (Kg)	Total Output (Kg)	Minimum Output (Kg)	Maximum Output (Kg)	Std. Devi. (Kg)
1	Shade Net Used	149	5622.75	837789	32	173000	14351.44
2	Shade Net Not Used	16	1740.5	27848	130	12000	3041.30
Total		165	5246.28	865637	32	173000	13712.9

Source: Primary Data

Table 5.17.1

Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of annual output in kgs is the same across categories of using of shade net	Independent Sample Mann-Whitney U Test	0.000	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

As table 5.17 depicts, the average annual output of shade net greenhouses was threefold higher than that of shade net not used greenhouses. As per table 5.17.1, this difference was statistically significant. In other words, the average output of the former was far higher than the latter. This makes it clear that a shade net is needed in a greenhouse to grow vegetables.

5.10.4 Annual Output across other Characteristics of Greenhouses

Greenhouses differ in terms of ventilation, stand, roof shape, and direction, in addition to the features listed above. Table 5.18 demonstrated, however, that there was no significant difference in the average product based on these factors. It specifies the test and level of significance for each feature.

Table 5.18
Other Major Features Greenhouse and their Test Statistics

SL No	Factor	Test	p ($\chi 2$)	Decision*
1	Across GH roofing (Gable type, Sawtooth type and Quonset type)	Kruskal-Wallis Test	0.209	No significant difference
2	Across Direction of GH (North-South and East-West)	Mann-Whitney Test	0.557	No significant difference
3	Across Ventilation Type (Naturally ventilated and Fan Ventilated)	Mann-Whitney Test	0.522	No significant difference
4	Across the Existence of GHs (Lean-to other buildings and separate existence)	Mann-Whitney Test	0.101	No significant difference

*The significance level is 0.05

5.11 Productivity of Greenhouse Vegetable Cultivation: Area-wise Analysis

Productivity is a measure of the efficiency with which goods or services are produced. Productivity is frequently expressed as a ratio of aggregate output to a single or aggregate input used in a production process, i.e., output per unit of input, typically over a specific time period. "Productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input use" (OECD 2001). Measuring productivity at the farm level entails gathering information on all outputs produced as well as the various inputs and production factors used. In general, because productivity is defined as the ratio of outputs to inputs, quantifying productivity necessitates not only a proper assessment of agricultural production for the holding's main crops or activities but also for minor crops and by-products such as hay used for fodder or manure. Farm productivity depends upon many factors, such as farm size, the socio-economic background of the farmers, the features of the farm, etc. Farm size, farmers' socioeconomic status, farm characteristics, and other factors all have an impact on farm productivity. The average annual output in kilogrammes per sq. m. of greenhouse area was taken as the measure of productivity. Productivity was first measured in kilogrammes of output per sq. m. per year, and then in kilogrammes of output per labour hour. The below section deals with the analysis of greenhouse productivity per sq. m.

5.12 Major Socio-economic Characteristics of Greenhouse Farmers and Productivity

The major socio-economic features here taken into consideration were gender, education, location, age, religion, and caste of the farmers. These features might have an influence on the productivity of the greenhouse area.

5.12.1 The Religion of the Farmer and Greenhouse Productivity

As mentioned earlier in terms of annual production, the religion of the farmer is not something that directly affects agricultural production. However, the following table examines how the performances of different religious groups differ and how they affect the productivity of greenhouse vegetable cultivation.

Table 5.19
Productivity across Religion of Greenhouse Farmers

SL No	Religion	Number	Average Output (kg/sq.m)	Minimum Output (kg/ sq. m)	Maximum Output (kg/sq.m)	Std. Devi. (kg/sq.m.)
1	Hindu	76	9.29	1.18	30.95	6.01
2	Christian	74	7.46	1.05	43.25	6.06
3	Muslim	13	5.19	1.98	10	2.21
4	No Religion (Institution)	2	10.87	8.75	12.99	2.99
Total		165	8.22	1.05	43.25	5.88

Source: Primary Data

Table 5.19.1
Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of productivity per sq. m. in kgs is the same across categories of religion of the farmers	Independent Sample Kruskal-Wallis Test	0.019	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

Table 5.19 gives information about the productivity of greenhouse farmers based on their religious affiliation. The information contains the number of farmers in each group, their average output (in kilogrammes per sq. m.), minimum and maximum outputs, and the standard deviation of output figures. Hindu farmers had the highest average output (9.29 kg/sq. m) and a wide range of productivity (1.18 to 30.95 kg/sq. m) with significant variability (standard deviation of 6.01 kg/sq. m). Christian farmers come in second with an average output of 7.46 kg/sq. m, as well as large variance (1.05 to 43.25 kg/sq. m), and a standard deviation of 6.06 kg/sq. m. Muslims have a lower average productivity (5.19 kg/sq. m) and less variability (1.98 to 10 kg/sq. m), with a standard deviation of 2.21 kg/sq. m. Institutional farmers who do not practice any religion have the highest average output (10.87 kg/sq. m) and a narrower range (8.75 to 12.99 kg/sq. m) with a standard deviation of 2.99 kg/sq. m. Overall, the evidence shows that productivity and variability vary across religious groups of greenhouse growers. According to table 5.19.1, this difference in productivity is statistically significant.

5.12.2 Productivity and Training

Whether or not the operators have received training specific to that task is an essential aspect that influences productivity. Farmers' training is critical since greenhouse vegetable cultivation necessitates a large number of technical resources. The production differential between farmers who have been trained for at least 7 days and those who have not is shown in the table below.

Table 5.20

Productivity across Duration of Training

SL No	Training	Number	Average Output (kg/sq. m.)	Minimum Output (kg/sq. m.)	Maximum Output (kg/sq. m.)	Std. Devi. (kg/ sq. m.)
1	Less than 7 days	76	7.23	0.5	30	5.82
2	7 days and more	89	9.06	1.05	43.25	5.84
Total		165	8.22	1.05	43.25	5.88

Source: Primary Data

Table 5.20.1

Hypothesis Test Summary

	Null Hypothesis	Test	Significance	Decision
1	The distribution of productivity per sq. m. in kgs is the same across categories of training duration	Independent Sample Mann-Whitney U Test	0.000	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

According to table 5.20, farmers who received fewer than 7 days of training produced an average of 7.23 kg/sq. m., with productivity ranging from 0.5 to 30 kg/sq. m. and a standard deviation of 5.82 kg/sq. m. Those who received training for 7 days or longer, on the other hand, have a higher average output of 9.06 kg/sq. m., ranging from 1.05 to 43.25 kg/sq. m., with a standard deviation of 5.84 kg/sq. m. Overall, the results show that farmers with longer training periods have greater average productivity and a broader range of output, indicating a possible positive correlation between training duration and greenhouse productivity. Further, table 5.20.1 illustrates that this difference in average output per sq. m. was statistically significant. However, there was no difference in the distribution of productivity across other major socioeconomic characteristics of the farmers. Table 5.21 demonstrates this.

Table 5.21

Productivity across other Major Socio-economic Features of Greenhouse Farmers and their Test Statistics

SL No	Factor	Test	p ($\chi 2$)	Decision*
1	Gender	Kruskal-Wallis Test	0.627	No significant difference
2	Across locations (Rural and Urban	Mann-Whitney Test	0.602	No significant difference
3	Across education of the farmer	Kruskal-Wallis Test	0.954	No significant difference
4	Across age of the farmer	Kruskal-Wallis Test	0.485	No significant difference
5	Across caste of the farmer	Kruskal-Wallis Test	0.262	No significant difference
6	Across full-time / part-time	Mann-Whitney Test	0.216	No significant difference
7	Across the main occupation of farmers	Kruskal-Wallis Test	0.644	No significant difference
8	Across landholding category	Kruskal-Wallis Test	0.782	No significant difference

*The significance level is 0.05

There was no significant variation in production across gender, location, education, age, caste, whether they worked full-time or part-time, major occupation, and landholding of the farmers, as shown in table 5.21.

5.13 Productivity of Different Types of Greenhouses

The structure, direction, and size of greenhouses constructed for vegetable cultivation in Kerala vary. Of these, the smallest has an area of only 10 sq. m., and the largest has an area of 4000 sq. m. A wide range of organic and non-organic farms can be found in greenhouses. It is imperative to examine whether these features vary in their productivity.

5.13.1 Productivity and Size of Greenhouses

The relationship between area and productivity in agriculture has always been a hotly debated topic among economists. Those who argue that productivity rises as land area decreases do so for their own reasons. They say this is because of the high utilisation of low-cost labour available in underdeveloped countries like India. On the other hand, the opposite group argues that as the size of farms increases, farmers can invest more and consequently apply modern technology and equipment to farming. This ultimately increases the productivity of large farms. However, it is worthwhile to examine how effective it is in greenhouse farming. The table below indicates the average production rate from the smallest to the largest greenhouses.

Table 5.22

Productivity across the Size of Greenhouses

SL No	Size of GHs	Number	Average Output (Kg/sq. m)	Minimum Output (Kg/ sq. m)	Maximum Output (Kg/ sq. m)	Std. Devi. (Kg/ sq. m)
1	Very Small (Upto100 sq. m)	19	7.48	1.98	18.5	4.57
2	Small (101 - 300 sq. m)	11	4.35	1.18	11.33	3.07
3	Medium (301-500 sq. m)	89	8.76	1.05	30.95	6.01
4	Large (501-1000 sq. m)	30	8.28	1.25	16	3.56
5	Very Large (Above1000 sq. m)	16	8.61	2.13	43.25	9.85
Total		165	8.22	1.05	43.25	5.88

Source: Primary Data

Table 5.22.1

Hypothesis Test Summary

SL No	Null Hypothesis	Test	Significance	Decision
1	The distribution of productivity per sq. m. in kgs is the same across categories of size of farms	Independent Sample Kruskal-Wallis Test	0.021	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

As per table 5.22, the average productivity of all sizes of greenhouses was 8.22 kg per sq. m. The productivity was highest for medium greenhouses (8.76 kg), followed by very large (8.61 kg) and large (8.28 kg). The least productivity was for small greenhouses (4.35 kg), followed by very small (7.48 kg). The productivity of small greenhouses was about half of that of medium, very large, and large greenhouses. The variation in productivity was highest among very large greenhouses, followed by the medium. Table 5.22.1 shows that this difference in productivity was statistically significant. A pairwise analysis is given in table 5.22.2. Accordingly, the difference in average productivity between pairs of small and medium and small and large was significantly different while all other pairs were not.

The relationship between farm size and productivity is an apple of dispute among economists. There are different arguments in connection with that. Economic analysis of these theories underscores the importance of considering various factors, such as labour intensity, economies of scale, technology adoption, institutional support, and crop type, when assessing the impact of farm size on productivity. The optimal farm size might vary depending on specific contexts and conditions, and policies should aim to support sustainable productivity across different farm sizes. The relationship between GH size and average output is not linear. Factors like intensive cultivation, technology adoption, management practices, and crop selection significantly influence productivity. The optimal size choice should consider factors such as resource efficiency, management capabilities, and overall profitability to achieve successful GH farming.

Table 5.22.2

Comparison of Productivity of Different Size of Greenhouses

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sign
Small versus Very Large Farms	-30.966	18.705	-1.656	0.098	0.978
Small versus Very Small Farms	35.722	18.093	1.97	0.048	0.488
Small versus Medium Farms	-47.153	15.263	-3.089	0.002	0.020
Small versus Large Farms	-49.724	16.833	-2.954	0.003	0.031
Very large versus Very small Farms	4.757	16.204	0.294	0.769	1.00
Very large versus Medium Farms	16.187	12.968	1.248	0.212	1.00
Very large versus Large Farms	18.758	14.784	1.269	0.204	1.00
Very small versus Medium Farms	-11.430	12.069	-0.947	0.344	1.00
Very small versus Large Farms	-14.002	14.002	-1.00	0.317	1.00
Medium versus Large Farms	-2.572	10.082	-0.255	0.799	1.00

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same
Asymptotic significances (2-sided tests) are displayed. The significance level is 0.05

5.13.2 Productivity and Covering of Greenhouses

Two different sorts of covering technologies are used in Kerala greenhouses. The most notable are those totally covered with transparent sheets, although sides covered with insect protection nets and roofed with transparent sheets are also present, although they are uncommon. Because this discrepancy influenced the greenhouse's temperature and humidity, it is important to look into the productivity disparity. This fact is illustrated in the table below.

Table 5.23
Productivity across the Nature of Covering of Greenhouses

SL No	Nature of Covering of GHs	Number	Average Output (kg/sq. m.)	Minimum Output (kg/ sq. m.)	Maximum Output (kg/ sq. m.)	Std. Devi. (kg/sq. m.)
1	Fully Covered	161	8.36	0.5	43.25	5.8
2	Not Fully Covered	4	2.28	1.69	2.95	0.551
Total		165	8.22	.5	43.25	5.88

Source: Primary Data

Table 5.23.1

Hypothesis Test Summary

	Null Hypothesis	Test	Significance	Decision
1	The distribution of productivity per sq. m. in kgs is the same across categories of covering of greenhouses	Independent Sample Mann-Whitney U Test	0.002	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

In terms of covering type, Table 5.23 shows that 97.5 percent of greenhouses were fully covered, while just 2.5 percent were not fully covered. The former's productivity was four times higher than the latter's (8.36 kg and 2.28 kg, respectively). The first category's greatest productivity was 43.25 kg, while that of the second category was only 2.95 kg. In fully covered greenhouses, the productivity variation was likewise substantial. This difference in productivity was statistically significant, as seen in table 5.23.1. As a result, the hypothesis that productivity distribution is the same across greenhouse-covering categories was rejected.

5.13.3 Productivity and Vertical Farming in Greenhouses

Vertical farming is one of the most promising aspects of greenhouse vegetable cultivation. Food crops may be conveniently cultivated using vertical farming by planting in vertically stacked layers to conserve space and require little energy and water for irrigation. Vertical farming is done in Kerala, although it is limited to a few crops. In comparison to horizontal farming, vertical farming requires less land and other inputs. As a result, comparing the productivity of these two techniques is beneficial.

Table 5.24

Productivity and Vertical Farming

SL No	Practice of Farming	Number	Average Output (kg/sq. m)	Minimum Output (kg/ sq. m)	Maximum Output (kg/ sq. m)	Std. Devi. (kg/ sq. m)
1	Have Vertical Farming	141	8.49	1.18	30.95	5.26
2	No Vertical Farming	24	6.64	1.05	43.25	8.66
Total		165	8.22	1.05	43.25	5.88

Source: Primary Data

Table 5.24.1

Hypothesis Test Summary

	Null Hypothesis	Test	Significance	Decision
1	The distribution of productivity per sq. m. in kgs is the same across categories of vertical farming	Independent Samples Mann-Whitney U Test	0.003	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

According to table 5.24, around 85 percent of farms had vertical farming practices. The average production for vertical farming farmers (141 in total) is 8.49 kg per sq. m., with productivity ranging from 1.18 to 30.95 kg per sq. m. and a standard deviation of 5.26 kg per sq. m. Farmers who do not practice vertical farming (24 in all) have a lower average production of 6.64 kg per sq. m., a broader range of 1.05 to 43.25 kg per sq. m., and a greater standard deviation of 8.66 kg per sq. m. Overall, the evidence suggests that greenhouse farmers who employ vertical farming have greater average productivity, more consistent results, and a narrower range of outputs than those who do not use vertical farming techniques. This difference in productivity was statistically significant, as seen in table 5.24.1.

5.13.4 Other Features of Greenhouses and Productivity

Aside from size and covering, greenhouses differ in terms of roof type, direction, use of shade nets, type of ventilation, existence, and farming method (organic vs. non-organic). Greenhouse productivity may also differ as a result. According to Mr. Anilkumar from Thalavadi in the Alappuzha district, the gable type is more productive than the sawtooth type since the temperature variation inside the greenhouse is less than the temperature outside (personal communication). However, according to this study, such parameters did not differentiate greenhouse productivity. The hypothesis test findings in relation to these parameters are summarised in table 5.25.

Table 5.25

Productivity across other Major Features of Greenhouses

SL No	Factor	Test	p ($\chi 2$)	Decision*
1	Type of Roof	Kruskal-Wallis Test	0.451	No significant difference
2	Direction of GHs	Mann-Whitney Test	0.885	No significant difference
3	Usage of Shade Net	Mann-Whitney Test	0.789	No significant difference
4	Nature of Ventilation	Mann-Whitney Test	0.878	No significant difference
5	Existence of GHs	Mann-Whitney Test	0.131	No significant difference
6	Method of Farming	Mann-Whitney Test	0.480	No significant difference

*The significance level is 0.05

5.14 Labour Productivity in Different Types of Greenhouses

The importance of labour productivity is equal to that of area-based productivity. The question here is how many vegetables can be produced in one hour of human labour. The cost of labour is the most important component in determining the cost of this process. Therefore, human labour must, without a doubt, be utilised effectively. It is necessary to investigate worker productivity in various greenhouses and settings.

5.14.1 Labour Productivity and Size of Greenhouses

Here we examine whether the productivity of labour is the same in greenhouses of different sizes. Greenhouses are divided into five categories, from the smallest to the largest. The table below analyses the differences in labour productivity between them. As the distribution was not normally distributed, non-parametric tests were used to infer conclusions.

Table 5.26

Labour Productivity across the Size of Greenhouses

SL No	Size of GHs	Number	Average Output (kg/ hr. L)	Minimum Output (kg/ hr. L)	Maximum Output (kg/ hr. L)	Std. Devi. (kg/ hr. L)
1	Very Small (Upto100 sq. m)	19	5.23	0.95	31	6.91
2	Small (101 - 300 sq. m)	11	4.84	0.88	10.63	3.47
3	Medium (301-500 sq. m)	89	9.66	0.5	54.55	7.47
4	Large (501-1000 sq. m)	30	13.57	0.93	44.12	7.6
5	Very Large (Above1000 sq. m)	16	17.46	6.6	63.6	14.9
Total		165	10.3	0.5	63.6	8.86

Source: Primary Data

Table 5.26.1
Hypothesis Test Summary

SL No	Null Hypothesis	Test	Significance	Decision
1	The distribution of labour productivity in kgs is the same across categories of size of farms	Independent Samples Kruskal-Wallis Test	0.000	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

Labour productivity grew as farm size increased, as shown in table 5.26. Very large farms produced the most per hour (17.46 kg), followed by large (13.57 kg), medium (9.66 kg), and very small farms (5.23 kg). Small farms have the lowest labour productivity. The increased utilisation of labour on small farms was the primary cause of this disparity. Large farms primarily relied on expensive hired labour. As a result, they used the least amount of labour possible. In the case of small and very small farms, on the other hand, the utilisation of own labour with no opportunity cost was significant. This difference in productivity was statistically significant, according to table 5.26.1. Table 5.26.2 also provides a paired comparison of productivity differences. As a result, except for the pairs of very small and small, small and medium, medium and very large, and large and very large, all productivity differences were statistically significant.

Table 5.26.2

Pairwise Comparison of Labour Productivity in Different Sizes of Greenhouses

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sign
Small versus Very Small Farms	-3.978	18.100	-0.220	0.826	1.00
Very small versus Medium Farms	-41.983	12.074	-3.477	0.001	0.005
Very small versus Large Farms	-74.425	14.007	-5.313	0.000	0.000
Very large versus Very small Farms	-76.311	16.210	-4.708	0.000	0.000
Small versus Medium Farms	-38.004	15.269	-2.489	0.013	0.128
Small versus Large Farms	-70.447	16.840	-4.183	0.000	0.000
Small versus Very Large Farms	-72.332	18.712	-3.866	0.000	0.000
Medium versus Large Farms	-32.443	10.086	-3.217	0.001	0.013
Very large versus Medium Farms	-34.328	12.973	-2.646	0.008	0.081
Very large versus Large Farms	-1.885	14.790	-0.127	0.899	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same
Asymptotic significances (2-sided tests) are displayed. The significance level is 0.05

5.14.2 Labour Productivity across Full-time and Part-time Activities

As previously stated, greenhouse vegetable cultivation was carried out as a full-time (15.8%) and part-time activity (84.2%). The attention paid by these two groups may differ, as full-timers may be able to complete activities more efficiently than part-timers. As a result, labour productivity could be different. This difference is examined in the table below.

Table 5.27

Labour Productivity across Nature of Farming Activity

SL No	Nature of Activity	Number	Average Output (kg/ hr. L)	Minimum Output (kg/ hr. L)	Maximum Output (kg/ hr. L)	Std. Devi. (kg/ hr. L)
1	Full-time	26	14.37	0.88	54.55	12.86
2	Part-time	139	9.53	0.6	63.6	7.73
Total		165	10.3	0.6	63.6	8.86

Source: Primary Data

Table 5.27.1

Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of labour productivity in kgs is the same across categories of full-time and part-time farmers	Independent Sample Mann-Whitney U Test	0.034	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

As expected, according to table 5.27, the average productivity of labour was high (14.37 kg) for full-time farmers while it was low (9.53 kg) for part-time farmers. The productivity of the former category was approximately 50 percent higher than the latter. As per table 5.27.1, this difference was statistically significant.

Table 5.28

Labour Productivity Across Other Major Features of Greenhouses/Farmers

SL No	Factor	Test	p ($\chi 2$)	Decision*
1	Type of Roof	Kruskal-Wallis Test	0.212	No Significant Difference
2	Direction of GHs	Mann-Whitney Test	0.578	
3	Usage of Shade Net	Mann-Whitney Test	0.056	
4	Nature of Ventilation	Mann-Whitney Test	0.344	
5	Existence of GHs	Mann-Whitney Test	0.073	
6	Method of Farming	Mann-Whitney Test	0.5	
7	Gender	Kruskal-Wallis Test	0.705	
8	Location	Mann-Whitney Test	0.191	
9	Education	Kruskal-Wallis Test	0.257	
10	Age	Kruskal-Wallis Test	0.528	
11	Religion	Kruskal-Wallis Test	0.082	
12	Caste	Kruskal-Wallis Test	0.389	
13	Main Occupation	Kruskal-Wallis Test	0.179	
14	Land Holding	Kruskal-Wallis Test	0.784	
15	Training	Mann-Whitney Test	0.058	

*The significance level is 0.05

Table 2.28 shows the other features of the greenhouses where the vegetables were grown and the socio-economic background of the farmers. However, it can be seen that labour productivity did not vary based on the factors mentioned herein. The size of greenhouse farms and the nature of the activity (full-time versus part-time) were the factors determining labour productivity in greenhouse vegetable cultivation.

5.15 Crop-wise Analysis of Greenhouse Vegetable Cultivation

In Kerala, various types of vegetables are grown in greenhouses. Many factors, including greenhouse design and the farmers' socio-economic status, can influence vegetable quantity and type. The following section discusses the cropping pattern of greenhouse vegetable cultivation in the state.

Table 5.29

Annual Output from Greenhouse Crops

SL No	Crop	Number of Farms		Output in Kgs	
		Number	%	Quantity	%
1	Tomato	48	29.09	35780	4.13
2	Capsicum	13	7.8	2985	0.34
3	Yardlong Bean	154	93.33	245630	28.38
4	Cabbage	12	6.67	5545	0.64
5	Cauliflower	11	4.85	4325	0.50
6	Salad Cucumber	115	69.70	454150	52.46
7	Green chilli	38	16.36	8702	1.01
8	Spinach	43	18.79	26954	3.11
9	Bitter gourd	54	24.85	54368	6.28
10	Brinjal	23	14.55	12103	1.40
11	Other	47	23.64	15095	1.74
Total				**865637**	**100**

Source: Primary Data

Ten important crops were grown in greenhouses in the state, according to Table 5.29. Yardlong beans (93.33%) were the most popular crop, followed by salad cucumbers (69.7%), tomatoes (29.09%), and bitter gourds (24.85%). The least-grown crop was cauliflower (4.85%), followed by cabbage (6.67%) and capsicum (7.8%). The quantity of output, on the other hand, revealed a different image. Salad cucumbers accounted for 52.46 percent of total greenhouse vegetable production, with yardlong beans accounting for the remaining 28.38 percent. Apart from bitter gourd (6.28%), tomato (4.13%), and amaranth (3.11%), all other crops played a minor role in production. In a nutshell, salad cucumber and yardlong beans were the crown jewels of Kerala greenhouse vegetable production (80.84%).

5.15.1 Salad Cucumber: Production and Productivity

As previously indicated, in terms of productivity, salad cucumbers are the most common crop grown in greenhouses in Kerala. Salad cucumbers contributed more than half of the entire output of greenhouse vegetable fields. So, it is best to look at both salad cucumber farms and other farms that do not grow salad cucumbers to see how much they produce and how productive their land and labour are.

Table 5.30

Production and Productivity of Salad Cucumber Cultivated Greenhouses

SL No	Cultivation of Salad Cucumber	Number	Average Output (in kgs)	Area Productivity (kg/ sq. m)	Labour Productivity (kg / hr. L)
1	Cultivated	115	6217.98	9.05	11.57
2	Not Cultivated	50	3011.38	6.30	7.38
Total		165	5246.28	8.22	10.30

Source: Primary Data

Table 5.30.1

Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of annual output is the same across categories of salad cucumber cultivated	Independent Samples Mann-Whitney U Test	0.000	Reject the null hypothesis
2	The distribution of productivity in kgs per sq. m. is the same across categories of salad cucumber cultivated		0.002	
3	The distribution of labour productivity in kgs is the same across categories of salad cucumber cultivated		0.000	

Asymptotic significances are displayed. The significance level is 0.05

Salad cucumber and non-salad cucumber growing greenhouses are compared in Table 5.30 for average production, area productivity, and labour productivity. The former's average output was more than double that of the latter. Similarly, in salad cucumber cultivating farms, area productivity and labour productivity were roughly 50 percent higher. Furthermore, the differences in average production, area productivity, and labour productivity were statistically significant, as shown in table 5.30.1.

5.15.2 Yardlong Bean: Production and Productivity

Table 5.31

Production and Productivity of Yardlong Bean Cultivated Greenhouses

SL No	Cultivation of Yardlong Bean	Number	Average Output (in kgs)	Area Productivity (kg/ sq. m)	Labour Productivity (kg / hr. L)
1	Cultivated	154	5376.28	8.44	10.38
2	Not Cultivated	11	3426.27	5.08	9.20
Total		165	5246.28	8.22	10.30

Source: Primary Data

As shown in table 5.31, there was a difference in average output, area productivity, and labour productivity between yardlong bean-producing greenhouse farms and others. On the contrary, only 6.7 percent of farms did not raise this crop. All of these figures were higher for farms in the first category. As seen in table 5.31.1, only the difference in area productivity was statistically significant, whereas the others were not.

Table 5.31.1

Hypothesis Test Summary

	Null Hypothesis	Test	Significance	Decision
1	The distribution of annual output is the same across categories of yardlong bean cultivated farms	Independent Samples Mann-Whitney U Test	0.207	Retain the null hypothesis
2	The distribution of productivity per sq. m. is the same across categories of yardlong bean cultivated farms		0.045	Reject the null hypothesis
3	The distribution of labour productivity per sq. m. is the same across categories of yardlong bean cultivated farms		0.360	Retain the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

5.16 Production Function in High-tech Vegetable Farming

The relationship between annual cost and yield was estimated using the Cobb-Douglas function (Cobb and Douglas, 1928). The vegetable yield was assumed to be a function of annual capital spending and human labour (both hired and owned). All values are expressed in rupees.

Cobb-Douglas Model $Q = AK^{\alpha} L^{\beta}$

Its Functional form is (Pahlavan, Omid, & Akram, 2012)

$$\ln Y_i = \ln A + \beta_1 \ln K + \beta_2 \ln L$$

With the expected sign of all positive

Table 5.32

Regression Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-1.321	.629	-2.100	.037
Log of Capital Expenditure (in Rs.)	.551	.086	6.404	.000
Log of Labour Expenditure (in Rs.)	.603	.099	6.099	.000
Adjusted R Square	0.725			
Prob (F-statistic)	.000			
Collinearity Statistics	Tolerance: .328, VIF: 3.052			
a. Dependent Variable: Log of Annual Yield (in Rs), b. Predictors: (Constant), Log of Labour Expenditure (in Rs.), Log of Capital Expenditure (in Rs.)				

Source: Author's calculation from primary data

The test revealed a model: $\ln Y_i = e^{-1.321} + 0.551 \ln K + 0.603 \ln L$

$$\ln Y_i = 0.267 + 0.55 \ln K + 0.603 \ln L$$

The coefficients were: Total Productivity (A) 0.267 (t=-2.1 & P= .037), Annual Capital Expenditure (β_1) 0.551 (t=6.404 & P=0.00) and Annual Labour expenditure

(β_2) 0.603 (t=6.1 P= 0.00). The other important values of the model were R^2: 0.725 and VIF: 3.052. Furthermore, sensitivity analysis revealed a return to scale of 1.154.

5.17 Conclusion

This chapter provided a thorough portrait of the respondent farmers. Accordingly, Kerala's high-tech vegetable farming was primarily carried out by male individual farmers from rural areas with an intermediate or higher education level. The majority of the farmers were between the ages of 41 and 70. Farmers who were Christians or Hindus dominated this occupation. Most farmers in the state were from the general category, and there were no SC or ST individuals among the high-tech farmers. For most of the farmers, this activity was a part-time business. Additionally, most farmers had marginal plots of land. Almost all of the farmers had received training. More than half of the high-tech farms used an organic farming method and were of medium size. When the number of pieces of equipment put in the greenhouses was considered, greenhouse farming in the state was a medium-tech activity. Full-time, trained farmers produced more on average than their part-time, less-trained counterparts. Small farms had the lowest area productivity, whereas medium-sized farms had the best. However, very large farms had the highest labour productivity, whereas small farms had the lowest. The crops that were most commonly grown in greenhouses in the state were salad cucumbers and yardlong beans. An increasing return to scale was an attribute of the state's high-tech vegetable farming.

CHAPTER VI
ECONOMIC VIABILITY OF HIGH-TECH FARMING

6.1 Introduction

The ability to earn a profit is crucial to the long-term success of any business. The ability to earn a profit is essential to the survival of any enterprise, whether it is industrial, commercial, or agricultural. Any business that consistently loses money is doomed to fail. Growing vegetables in greenhouses is a complex endeavour. Large sums of money and careful attention are needed for this method. Therefore, it is essential to assess its economic viability in addition to its technological feasibility.

Numerous research projects have investigated the technical viability of greenhouse vegetable cultivation, especially from the standpoint of agricultural professionals; however, a thorough economic study is noticeably lacking in this field. The economic success of greenhouse vegetable farming in Kerala over the past decade has become especially relevant here. All the investigated greenhouses benefited from government subsidies. However, the profitability of this endeavour was being evaluated separately from other endeavours, both subsidised and unsubsidised.

While research into the technical side of greenhouse vegetable farming has been extensive, research into the broader economic impact has lagged far behind. With a decade of data, the following analysis of the economic success of this practice in Kerala provides insight into the complex relationship between investment, subsidy, and profitability in this specialised area of agriculture.

6.2 Annual Cost of Greenhouse Vegetable Cultivation without Subsidy

On an annualised basis, the cost of greenhouse cultivation was calculated. The costs were split into two categories: fixed and variable. The annual fixed cost was calculated by dividing the cost of greenhouse construction by ten years. The structure's estimated lifespan is ten years. Because the grazing sheet needed to be replaced in the meantime, the scrap value was ignored. That cost was adjusted to the scrap value of the GI structure. The cost of recruiting labourers, the cost of seeds and seedlings, manure, pesticides, minor equipment, the cost of energy for irrigation, fans, foggers, and other equipment, and the cost of transportation were all variable costs. The variable cost also included the interest cost of the borrowed capital, which was calculated at a rate of 7 percent. Tables from 6.1 to 6.4 show the estimated value of various agricultural cost concepts, like A1, B1, C2, and C3. The largest cost, C3, included annual fixed costs, annual costs for hired labour, annual costs for materials, the value of interest on own capital and labour, and 10 percent of C2 cost for management costs. Because the rental value of the land on which the greenhouse was built and the amount of land tax were unavailable, these items were omitted from the calculation.

Table 6.1

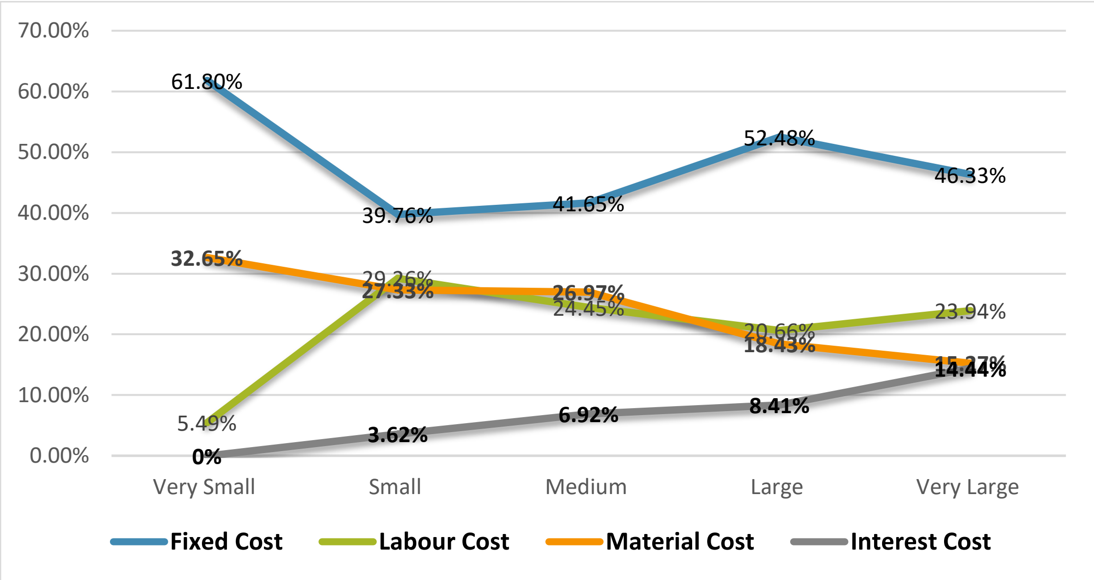
Annual Cost (A1) Components of Various Sizes of Greenhouses

SL No	Size of GH	Number	Fixed Cost (Rs)	Labour Cost (Rs)	Material Cost (Rs)	Interest Cost (Rs)	Total Cost A1 (Rs)
1	Very Small (Upto100 sq. m)	19	7105 (61.8)	631 (5.49)	3752 (32.65)	00 (0)	11489 (100)
2	Small (101 - 300 sq. m)	11	24454 (39.76)	18000 (29.26)	16812 (27.33)	2227 (3.62)	61500 (100)
3	Medium (301-500 sq. m)	89	62382 (41.65)	36620 (24.45)	40390 (26.97)	10365 (6.92)	149758 (100)
4	Large (501-1000 sq. m)	30	145553 (52.48)	57316 (20.66)	51116 (18.43)	23333 (8.41)	277300 (100)
5	Very Large (Above 1000 sq. m)	16	238312 (46.33)	123125 (23.94)	78575 (15.27)	74287 (14.44)	514300 (100)
All		165	85666 (45.93)	43386 (23.26)	40253 (21.58)	17185 (9.21)	186491 (100)

Source: Primary Data. Values in parenthesis are percentages of row total

Figure 6.1

Proportion of Various Elements of Cost A1 (Without Subsidy)



Source: Primary Data

The proportion of the annual fixed cost, labour cost, material cost, and interest cost on borrowed capital differed for different sizes of greenhouses, as shown in table 6.1 and figure 6.1. The values displayed were the size category's average. As a result, the fixed cost was highest for very small (61.84%) greenhouses, followed by large (52.4%) and very large (46.34%). Small greenhouses had the lowest amount of fixed costs (39.76%), followed by medium greenhouses (41.65%). Very small greenhouses (5.49%) had the lowest share of labour costs, followed by large greenhouses (24.45 %). As the size of the farm grew, the proportion of material costs decreased. The major components of material costs were expenditure on seeds and seedlings, fertilisers and manure, pesticides, irrigation, transportation, and miscellaneous items. For extremely small greenhouses, the percentage of interest cost was nil, but it climbed as the size of the farm grew. The total cost (A1) of various-sized greenhouses is shown in the table's last column. Accordingly, very small greenhouses cost Rs. 11489, small greenhouses cost Rs. 61500, medium greenhouses cost Rs. 149758, large greenhouses cost Rs. 277300, and very large greenhouses cost Rs. 514300.

Table 6.2 displays the estimated annual cost, B1. The interest rate on owners' own capital was estimated at 6 percent per annum, which was the average interest rate on the deposits for various time periods, according to the respondents' information. For very small to very large greenhouses, the interest amount ranged from Rs. 2452 to Rs. 70919.

Owners' investments in very small greenhouses were higher than in medium and very large greenhouses. As a result, the share of interest costs for very small greenhouses was the highest (17.58%), followed by large (15.09%) and small (13.56%). Medium greenhouses had the lowest proportion (10.5%), followed by very large greenhouses (12.11%). For extremely small and very big greenhouses, the B1 cost ranged from Rs. 13941 to Rs. 585219.

Table 6.2

Annual Cost (B1) Components of Various Sizes of Greenhouses

SL No	Size of GH	Number	Total Cost A1 (Rs)	Interest of Owners' Own Capital (Rs)	Total Cost B1 (Rs)
1	Very Small (Upto100 sq. m)	19	11489 (82.41%)	2452 (17.58%)	13941 (100%)
2	Small (101 - 300 sq. m)	11	61500 (86.43%)	9654 (13.56%)	71154 (100%)
3	Medium (301-500 sq. m)	89	149758 (89.49%)	17578 (10.5%)	167336 (100%)
4	Large (501-1000 sq. m)	30	277300 (84.92%)	49242 (15.09%)	326542 (100%)
5	Very Large (Above 1000 sq. m)	16	514300 (87.88%)	70919 (12.11%)	585219 (100%)
All		165	186491 (87.66%)	26237 (12.33%)	212729 (100%)

Source: Primary Data

Table 6.3

Annual Cost (C2) Components of Various Sizes of Greenhouses

SL No	Size of GH	Number	Total Cost B1 (Rs)	Imputed value of own and family labour (Rs)	Total Cost C2 (Rs)
1	Very Small (Up to 100 sq. m)	19	13941 (58.64%)	9830 (41.36%)	23771 (100%)
2	Small (101 - 300 sq. m)	11	71154 (85.18%)	12373 (14.81%)	83528 (100%)
3	Medium (301-500 sq. m)	89	167336 (89.11%)	20436 (10.88%)	187773 (100%)
4	Large (501-1000 sq. m)	30	326542 (93.51%)	22641 (6.48%)	349184 (100%)
5	Very Large (Above 1000 sq. m)	16	585219 (95.12%)	29994 (4.87%)	615214 (100%)
All		165	212729 (91.40%)	20005 (8.51%)	232735 (100%)

Source: Primary Data

Table 6.3 shows how cost C2 was estimated by adding the imputed value of farmers' own and family labour. The hourly wage of hired labourers was used to calculate the wage rate. As the farm size went from very small to very large, the share of the imputed value of owners and family labour declined. Because extremely small farms rely on their own labour for cultivation, their share of the total cost, C2, was 41.81 percent.

However, it fell to 14.81 percent, 10.88 percent, 6.48 percent, and 4.87 percent for small, medium, large, and very large farms, respectively. It was 8.51 percent for all farms combined. C2 total costs were Rs. 23771, Rs. 83528, Rs. 187773, Rs. 349184, and Rs. 615214 for very tiny, small, medium, large, and very large farms, respectively. However, for small, medium, large, and very large farms, it fell to 14.81 percent, 10.88 percent, 6.48 percent, and 4.87 percent, respectively. It was 8.51 percent for all farms. The total cost C2 for very small, small, medium, large, and very large farms was Rs. 23771, Rs. 83528, Rs. 187773, Rs. 349184, and Rs. 615214, respectively.

Table 6.4

Annual Cost (C3) Components of Various Sizes of Greenhouses

SL No	Size of GH	Number	Total Cost C2 (Rs)	Annual Management Cost (Rs) 10% of C2	Total Cost C3 (Rs)
1	Very Small (Upto100 sq. m)	19	23771	2377	26149
2	Small (101 - 300 sq. m)	11	83528	8352	91881
3	Medium (301-500 sq. m)	89	187773	18777	206551
4	Large (501-1000 sq. m)	30	349184	34918	384103
5	Very Large (Above 1000 sq. m)	16	615214	61521	676735
All		165	232735	23273	256008

Source: Primary Data

Table 6.4 displays the cost concept of C3 estimation by combining management costs with C2 costs at a rate of 10 percent of the latter. As a result, for very small, small, medium, large, and very large farms, cost C3, which covered all costs linked to farming activities, was Rs. 26149, Rs. 91881, Rs. 206551, Rs. 384103, and Rs. 676735, respectively. It was Rs. 256008 for all farms.

6.3 Average Cost of Production

The estimated value of cost measures A1, B1, C2, and C3 is shown in tables 6.1–6.4. When determining the economic viability of a business, it is unavoidable to look at the average cost of producing one unit of the product rather than the overall cost. The following tables show the average cost of producing one kilogramme of vegetables in various greenhouse categories.

Table 6.5.1 a

Average Cost per kg of Vegetables: A1 Cost Components among Different Sizes of Greenhouses (without subsidy)

SL No	Cost Items (Rs)	Size of GH Farms				
		Very Small (Up to 100 sq. m)	Small (101 - 300 sq. m)	Medium (301-500 sq. m)	Large (501-1000 sq.m.)	Very Large (Above 1000sq.m.)
1	Value of hired labour	5.38	28.08	18.8	14.34	14.39
2	Seeds/Seedlings	2.4	5.74	1.97	1.51	0.991
3	Fertilizer/Manure	8.13	8.25	5.23	3.32	3.00
4	Pesticides/fungicides	1.12	2.43	1.18	0.72	0.47
5	Irrigation	1.55	6.93	3.11	1.74	1.38
6	Interest on working capital	00	2.21	2.1	1.45	2.71
7	Transport	0.83	5.26	3.68	1.89	2.30
8	Depreciation (GHs)	22.75	25.84	17.9	18.55	16.51
7	Miscellaneous	9.91	18.64	9.62	9.85	9.00
Total (A1)		**52.07**	**100.38**	**63.59**	**53.37**	**50.76**
8	Interest on fixed capital + rental value	10.35	16.51	7.8	9.39	6.61
9	The imputed value of own labour	44.64	23.57	9.25	4.49	3.58
10	Managerial Cost	10.71	14.04	8.06	6.72	6.09

Source: Primary Data

Table 6.5.1 provides information about the average cost per kilogramme (kg) of vegetables produced in different sizes of GHs, categorised by various cost components. The table compares these cost components across five different sizes of greenhouse farms. The data reveals that the cost of hired labour varies across different sizes of greenhouse farms. Small-sized GHs seem to have the highest cost of hired labour, followed by very large and medium-sized GHs. The very small and large-sized GHs have relatively lower costs for hired labour. This information can be helpful for greenhouse managers and policymakers to understand how labour costs are distributed across different sizes of greenhouse operations. A similar pattern is visible for all other cost components. "Small" greenhouse farms generally have higher costs in several categories compared to larger farms, and the cost distribution varies across different cost components. Larger GH farms benefit from economies of scale. When operations are scaled up, certain costs, such as labour, equipment, and infrastructure, can be spread across a larger production area. This leads to lower costs per unit of production. In contrast, small farms may have to bear these costs on a relatively smaller output, resulting in higher average costs. The very low area productivity and labour productivity in small GH farms compared to other size categories might be the reason for the higher average cost per kg of output.

The data in the table suggests that the combined cost of interest on fixed capital and rental value is generally higher for smaller and medium-sized GH farms, while the imputed value of own labour is higher for very small farms and decreases as the size of the farm increases. These findings highlight the dynamics of cost allocation and labour considerations across different sizes of GH operations.

Table 6.5.1 b

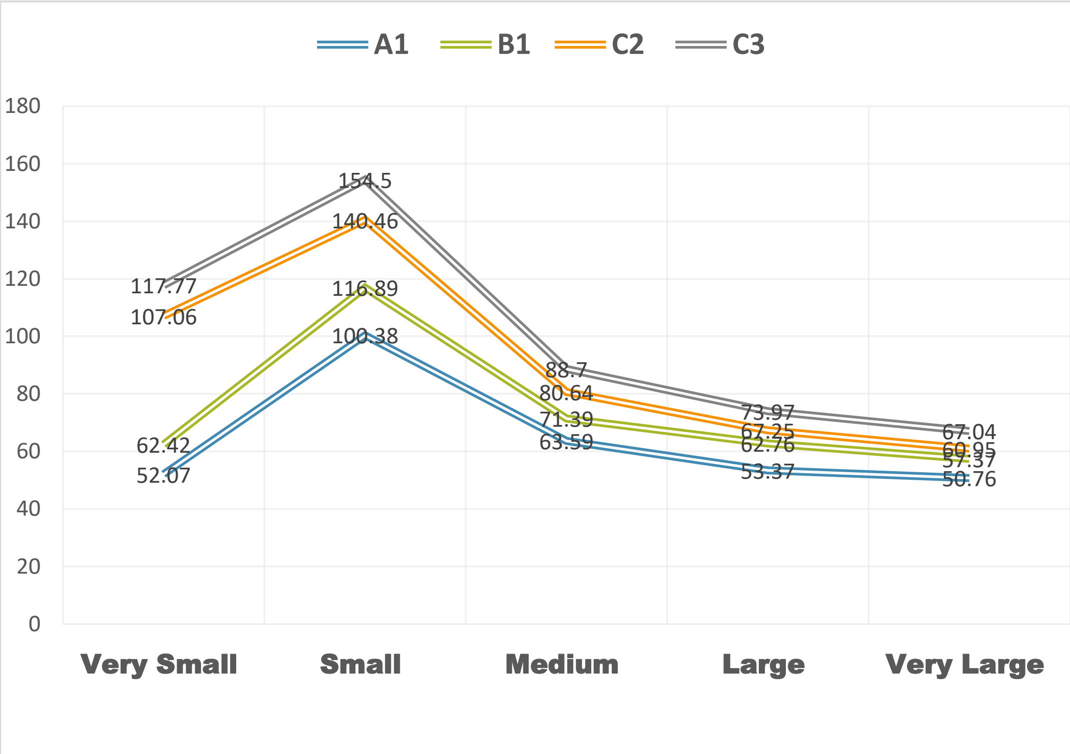
Average Cost per kg of Vegetables: A1, B1, C2 and C3 among Different Sizes of Greenhouses without Subsidy

SL No	Size of GH	Number	Average Cost A1 Rs.	Average Cost B1 Rs.	Average Cost C2 Rs.	Average Cost C3 Rs.
1	Very Small (Up to 100 sq. m)	19	52.07	62.42	107.06	117.77
2	Small (101 - 300 sq. m)	11	100.38	116.89	140.46	154.5
3	Medium (301-500 sq. m)	89	63.59	71.39	80.64	88.70
4	Large (501-1000 sq. m)	30	53.37	62.76	67.25	73.97
5	Very Large (Above 1000 sq. m)	16	50.76	57.37	60.95	67.04
All		165	61.60	70.45	83.34	91.6

Source: Primary Data

Figure 6.2

Average Cost A1, B1, C2 and C3 (in Rs per Kg)



Source: Primary Data

Table 6.5.2

Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of average A1 cost is the same across categories of size of farms	Independent Samples Kruskal-Wallis Test	0.121	Retain the null hypothesis
2	The distribution of average B1 cost is the same across categories of size of farms		0.120	Retain the null hypothesis
3	The distribution of average C2 cost is the same across categories of size of farms		0.000	Reject the null hypothesis
4	The distribution of average C3 cost is the same across categories of size of farms		0.000	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

All cost figures followed the same pattern of movement from very small to very large greenhouses, as shown in table 6.5.1 and figure 6.2. Small greenhouses had the highest average cost, followed by very small greenhouses for C2 and C3 values. Very large greenhouses had the lowest average cost, followed by large greenhouses. In the case of A1 and B1 costs, there was a slight discrepancy. Despite the fact that small greenhouses had the highest average cost, medium-sized greenhouses had the second-highest average cost. The difference between C3 and A1 was greatest for very small and small greenhouses since their paid-out costs were minimal because they relied mostly on their own labour and capital to manage the farming activity. However, differences in A1 and B1 between different-sized greenhouses were not statistically significant, according to table 6.5.2, although differences in C2 and C3 were.

Table 6.6.1

Average Costs (per kg of vegetables) of Trained and Untrained Farmers

SL No	Level of Training	Number	Average Cost A1 Rs.	Average Cost B1 Rs.	Average Cost C2 Rs.	Average Cost C3 Rs.
1	Less than 7 days	76	72.11	81.03	99.06	108.97
2	7 days and more	89	52.53	61.33	69.77	76.74
All		165	61.60	70.45	83.34	91.6

Source: Primary Data

In greenhouse vegetable production, as in any other production activity, training the operators is a crucial approach for optimising output and costs. In Table 6.6.1, the values of different cost metrics for trained and untrained or insufficiently trained farmers were compared. Accordingly, the costs borne by these two types of farmers were vastly different. The untrained farmers' total paid-out cost (A1) was 37 percent more than their trained counterparts. B1 had a 32.12 percent difference, while C2 and C3 both had a 42 percent difference. As per table 6.6.2, these differences in average costs were statistically significant for all cost metrics.

Table 6.6.2

Hypothesis Test Summary

Null Hypothesis		Test	Significance	Decision
1	The distribution of average A1 cost is the same across categories of training duration	Independent Samples Mann-Whitney U Test	0.029	Reject the null hypothesis
2	The distribution of average B1 cost is the same across categories of training duration		0.022	Reject the null hypothesis
3	The distribution of average C2 cost is the same across categories of training duration		0.012	Reject the null hypothesis
4	The distribution of average C3 cost is the same across categories of training duration		0.012	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

6.3.1 Relationship Between Experience and Cost of Production

Normally, an experienced operator can run the production activity at a lower cost compared to their non-experienced counterparts. In greenhouse farming too, there were farmers with many years of experience and those with no experience. Therefore, it was necessary to analyse the correlation between years of experience and the average cost.

Table 6.7

Correlation between Years of Experience and Cost of Production

			Average Cost C3
Spearman's rho	Years of Experience	Correlation Coefficient	-0.175*
		p (2-tailed)	0.025
		N	165

Table 6.7 depicts the Spearman rank correlation result. As expected, there was a negative correlation between years of experience and the cost of production. For simplicity, the broadest measure of cost, C3, was taken into consideration as it incorporated both paid-out and imputed costs related to cultivation. This correlation was statistically significant. In greenhouse farming, as in various economic

activities, experience often leads to more efficient practices, better resource utilisation, and a deeper understanding of optimal techniques. This aligns with the negative correlation observed between years of experience and the cost of production in the analysed data, as presented in table 6.7. Just as an experienced operator can run production at a lower cost, the learning curve theory predicts that as more units are produced (or more time is spent cultivating), the cost of production tends to decrease.

6.3.2 Other Factors and Differences in Average Cost

Aside from factors such as cultivation method, roof type, application of own ideas, full-time versus part-time activity, diverse farmer jobs, and the number of crops cultivated, other factors may have an impact on the average cost of greenhouse vegetable growing. These parameters are depicted in table 6.8 along with their actual significance levels and tests. As a result, while the actual p values of the tests were all above 0.05, these factors were not significant in distinguishing these distributions.

Table 6.8

Other Factors, Tests, and P Values of Cost Estimates A1, B1, C2 and C3

SL No	Factor	Test	A1 p	B1 p	C2 p	C3 p
1	Method of Cultivation (Across Organic and Non-organic	Mann-Whitney U test	0.557	0.503	0.168	0.168
2	Roof Type (Across Gable, Sawtooth, Quonset)	Kruskal-Wallis Test	0.241	0.315	0.439	0.439
3	Application of Own Idea in Farming	Mann-Whitney U test	0.619	0.512	0.145	0.145
4	Across full-time and part-time activity	Mann-Whitney U test	0.238	0.261	0.102	0.102
5	Across main occupations of GH farmers	Kruskal-Wallis Test	0.528	0.531	0.326	0.326
6	Number of Crops Cultivated	Kruskal-Wallis Test	0.272	0.237	0.242	0.242

Source: Author’s Estimation

6.4 Annual Cost of Greenhouse Vegetable Cultivation with Subsidy

As mentioned earlier, greenhouse vegetable cultivation is a highly subsidised activity. The central government, through the NHM, and the state government, through the SHM, both provide substantial subsidies of up to 75 percent of the construction cost, subject to certain limitations. This amount of subsidy was very helpful to the farmers to meet the heavy expenditure required at the beginning stage of cultivation. The estimation of various cost measures in the presence of subsidies is given in the following table.

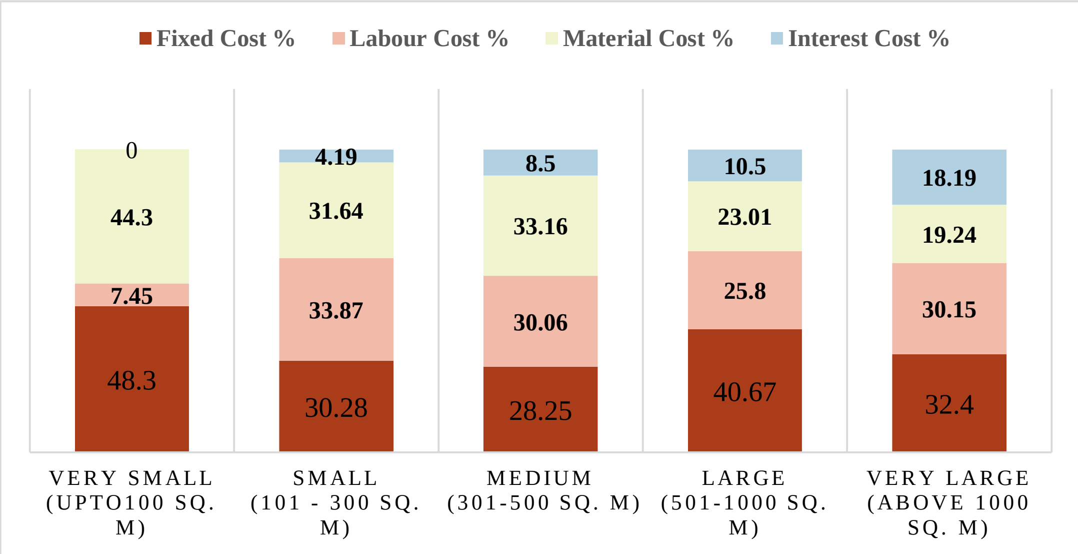
Table 6.9
Components of Annual Cost (A1) of Various Sizes of Greenhouses with Subsidy

SL No	Size of GH	Number	Fixed Cost (Rs)	Labour Cost (Rs)	Material Cost (Rs)	Interest Cost (Rs)	Total Cost A1 (Rs)
1	Very Small (Up to 100 sq. m)	19	4086 (48.3)	631 (7.45)	3752 (44.30)	00 (0)	8471 (100)
2	Small (101 - 300 sq. m)	11	16090 (30.28)	18000 (33.87)	16812 (31.64)	2227 (4.19)	53135 (100)
3	Medium (301-500 sq. m)	89	34412 (28.25)	36620 (30.06)	40390 (33.16)	10365 (8.5)	121787 (100)
4	Large (501-1000 sq. m)	30	90331 (40.67)	57316 (25.8)	51116 (23.01)	23333 (10.5)	222096 (100)
5	Very Large (Above 1000 sq. m)	16	132280 (32.4)	123125 (30.15)	78575 (19.24)	74287 (18.19)	408267 (100)
All		165	49356 (32.86)	43386 (28.88)	40253 (26.80)	17185 (11.44)	150180 (100)

Source: Primary Data. Values in parenthesis are percentages of the row total

Figure 6.3

Proportion of Various Elements of A1 Cost of Different GHs with Subsidy



Source: Primary Data

Table 6.9 shows the annual paid cost, A1, of various greenhouse sizes. According to the table, the average annual cost for very small greenhouses after subtracting the subsidy from the total construction cost was Rs. 8471, then it rose to Rs. 53135, Rs. 121787, Rs. 222096, and Rs. 408267 for small, medium, large, and very large greenhouses, respectively. The annual average cost per greenhouse was Rs. 150180 for all greenhouses combined. Furthermore, figure 6.3 shows that the very small greenhouses had the highest proportion of fixed costs (48.1%), followed by the large greenhouses (40.67%). In terms of material costs, very small greenhouses incurred the highest average cost (44.3%), followed by medium greenhouses (33.16%). Small greenhouses have the highest proportion of paid-out labour costs (33.87%), followed by very large (30.15%) and medium (30.06%) greenhouses. Very small greenhouses had the lowest proportion of paid-out labour costs (7.45%). For the other sizes, the proportion ranged from 25.8% to 33.87%. This phenomenon was caused by very small greenhouse farmers' reliance on their own labour. The proportion of interest costs as a percentage of total costs increased as the greenhouse size increased. In other words, large farmers were more likely to borrow money to build greenhouses, while small farmers mostly used their own money.

Table 6.10

Annual Cost B1, C2 and C3 of Various Sizes of Greenhouses with Subsidy

SL No	Size of GH	Number	Total Cost B1(Rs)	Total Cost C2 (Rs)	Total Cost C3 (Rs)
1	Very Small (Up to100 sq. m)	19	10923	20753	22828
2	Small (101 - 300 sq. m)	11	62790	75164	82681
3	Medium (301-500 sq. m)	89	139367	159804	175784
4	Large (501-1000 sq. m)	30	271340	293982	323380
5	Very Large (Above 1000 sq. m)	16	479187	509182	560100
All		165	176419	186424	216067

Source: Primary Data

Table 6.10 shows the estimated annual costs (B1, C2, and C3) for various sizes of greenhouses after the government subsidy is deducted. Accordingly, the average annual cost (C3) of very small greenhouses was Rs. 22828 and Rs. 560100 for a very large greenhouse. The total cost of all greenhouse sizes was Rs. 216067. The table and figures below compare the cost, C3, of greenhouses of different sizes with and without government subsidies.

Table 6.11

Annual Cost C3 of Various Sizes of Greenhouses with and without Subsidy: A Comparison

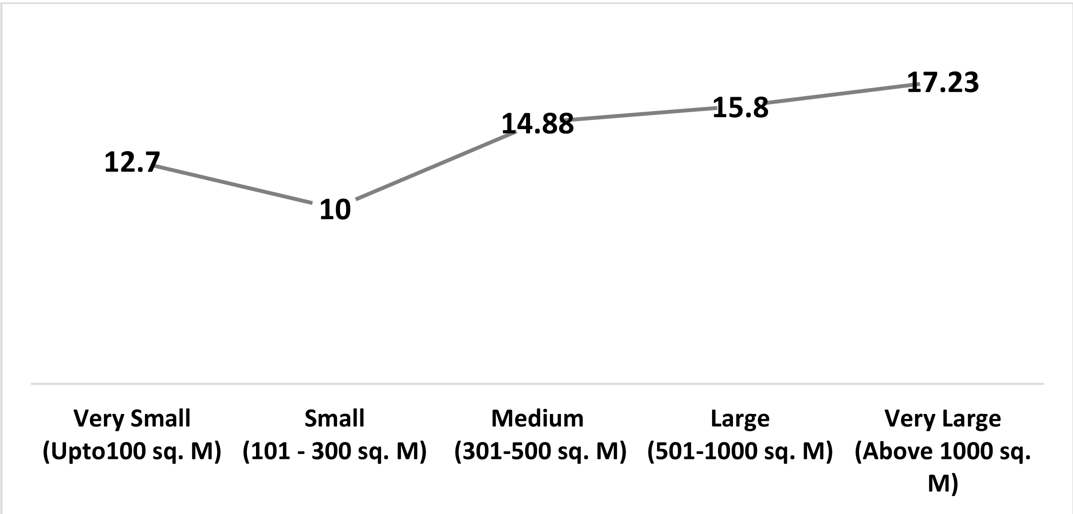
SL No	Size of GH	C3 with Subsidy	C3 without Subsidy	Subsidy	Proportion of Costs met through Subsidy
1	Very Small (Up to100 sq. m)	22828	26149	3321	12.7
2	Small (101 - 300 sq. m)	82681	91881	9200	10.0
3	Medium (301-500 sq. m)	175784	206551	30767	14.88
4	Large (501-1000 sq. m)	323380	384103	60723	15.8
5	Very Large (Above 1000 sq. m)	560100	676735	116635	17.23
All		216067	256008	39941	15.6

Source: Primary Data

Table 6.11 and figure 6.4 show the proportion of the annual cost (C3) covered by subsidies provided by both the federal and state governments. Accordingly, 15.6 percent of the total annual cost was covered by subsidies for all greenhouses. Very large greenhouses had the highest proportion (17.23%), followed by large (15.8%) and medium (14.88%) greenhouses. Small (10%) greenhouses had the lowest proportion, followed by very small (12.7%) greenhouses. In other words, very large and large greenhouses received a subsidy that was higher than the average (15.6%), while small, very small, and medium-sized greenhouses received a subsidy that was lower than the average.

Figure 6.4

Proportion of Costs Covered through Subsidy by Various Sizes of GHS



Source: Primary Data

6.5 Average Cost of Production with Subsidy

The estimated value of cost measures A1, B1, C2, and C3 with subsidies is shown in tables 6.9 and 6.10. As mentioned earlier, when determining the economic viability of a business, it is unavoidable to look at the average cost of producing one unit of the product rather than the overall cost. The following tables show the average cost of producing one kg of vegetables in various greenhouse categories after deducting the subsidy for greenhouse construction.

Table 6.12.1 illustrates the values of average cost, A1, B1, C2, and C3. All these cost figures resembled a similar pattern for various sizes of greenhouses, except for small greenhouses. Except for small, average costs B1, C2, and C3 decreased as greenhouse size increased. For average A1 and B1, the lowest figures were booked by very small greenhouses because of their less reliance on paid costs and interest costs. However, for small, medium, large, and very large greenhouses, the average cost declined with the increase in farm size. In the cases of C2 and C3, the highest average value was booked by the small greenhouses, then it declined as the farm size increased, considering very small greenhouses as an exception. Regarding the average cost, very large greenhouses are more economical compared to other-sized greenhouses. Moreover, table 6.12.2 illustrates that these differences in average costs were statistically significant except for cost B1 at the level of significance of 0.05.

Table 6.12.1

Average Cost: A1, B1, C2 and C3 per kg among Different Sizes of Greenhouses with Subsidy

SL No	Size of GH	Number	Average Cost A1 Rs.	Average Cost B1 Rs.	Average Cost C2 Rs.	Average Cost C3 Rs.
1	Very Small (Up to100 sq. m)	19	35.19	45.53	90.17	99.19
2	Small (101 - 300 sq. m)	11	89.14	105.65	129.22	142.14
3	Medium (301-500 sq. m)	89	52.67	60.47	69.72	76.69
4	Large (501-1000 sq. m)	30	42.43	51.81	56.31	61.94
5	Very Large (Above 1000 sq. m)	16	39.01	45.62	49.2	54.12
All		165	49.88	58.74	71.62	78.79

Source: Primary Data

Table 6.12.2

Hypothesis Test Summary

	Null Hypothesis	Test	Significance	Decision
1	The distribution of average A1 cost with subsidy is the same across categories of size of farms	Independent Samples Kruskal-Wallis Test	0.045	Reject the null hypothesis
2	The distribution of average B1 cost with subsidy is the same across categories of size of farms		0.072	Retained the null hypothesis
3	The distribution of average C2 cost with subsidy is the same across categories of size of farms		0.000	Reject the null hypothesis
4	The distribution of average C3 cost with subsidy is the same across categories of size of farms		0.000	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

Table 6.13
Average Cost C3 of Various Sizes of
Greenhouses with and without Subsidy: A Comparison

SL No	Size of GH	Average C3 with Subsidy Per Kg Rs.	Average C3 without Subsidy Per Kg Rs.	Subsidy Per Kg Rs.	Average Costs met through Subsidy %
1	Very Small (Upto100 sq. m)	99.19	117.77	18.58	15.77
2	Small (101 - 300 sq. m)	142.14	154.5	12.36	8.00
3	Medium (301-500 sq. m)	76.69	88.70	12.01	13.54
4	Large (501-1000 sq. m)	61.94	73.97	12.03	16.26
5	Very Large (Above 1000 sq. m)	54.12	67.04	12.92	19.57
All		78.79	91.6	12.7	13.86

Source: Primary Data

Table 6.13 shows how much of the average cost of C3 is covered by subsidies for various sizes of greenhouses to produce one kg of vegetables. As a result, very large greenhouses (19.57%) received the most subsidies, followed by large (16.26%) and very small greenhouses (15.77%). The least amount of subsidy (8%) was received by small greenhouses, followed by medium greenhouses (13.54%). In other words, very large, large, and very small-sized greenhouses received above-average subsidies, whereas small and medium-sized greenhouses received below-average subsidies. The share of subsidies to meet expenditures increased as the farm size increased from small to very large by holding very small greenhouses aside.

6.6 Cost-Output Elasticity of Greenhouses

The cost of production is mostly determined by the volume of output. The cost-output elasticity is a measure of how responsive the total cost is to a change in output. This value is critical for determining whether economies of scale exist. The regression result from which cost-output elasticity can be calculated is shown in the table below.

Table 6.14
Cost-Output Elasticity: Regression Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	7.015	0.261	26.85	0.000
Log of Output (in Kg.)	0.625	0.33	19.03	0.000
Adjusted R Square	0.689			
Prob (F-statistic)	0.000			
a. Dependent Variable: Log of Cost C3(in Rs), b. Predictors: (Constant), Log of Output (in Kg.)				

Source: Author's calculation from primary data

The regression analysis results are shown in table 6.14. The dependent and independent variables were the logs of cost C3 and output, respectively. There were increasing returns to scale because the regression coefficient was 0.625. A one percent increase in output only increased the total cost of C3 by 0.625 percent. Because the probability of F and t was less than 0.05, this relationship was statistically significant. Furthermore, changes in output explained 68.9% of the variation in total cost.

6.7 Marketing and Revenue Generation of Greenhouses

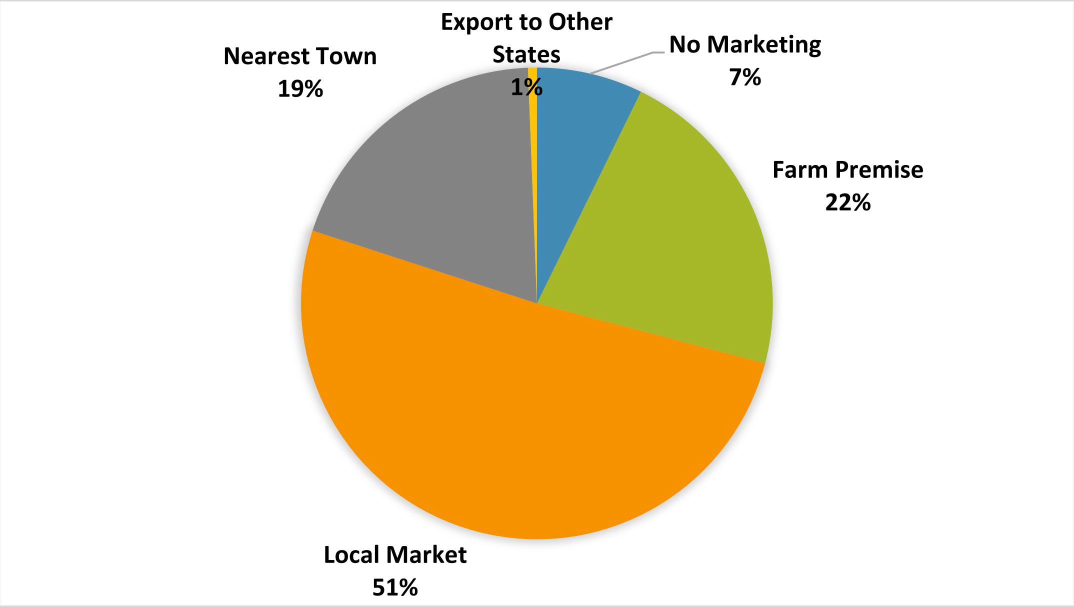
The first of two factors that affect an economic activity's financial viability is cost, and the second is revenue. The costs were covered in detail in the preceding section. The issue of revenue generation must now be thoroughly investigated. The first section discusses the product markets. The revenue from product sales in these markets is then examined.

6.7.1 Market for Greenhouse Crops

There are usually various markets for vegetables grown in greenhouses. Lots of sales take place on or near the farm. These products can be found in markets in nearby cities and other states, and rarely in other countries. The picture below shows where the vegetables grown in greenhouses in Kerala are mainly sold.

Figure 6.5

Marketing of Greenhouse Vegetable Crops



Source: Primary Data

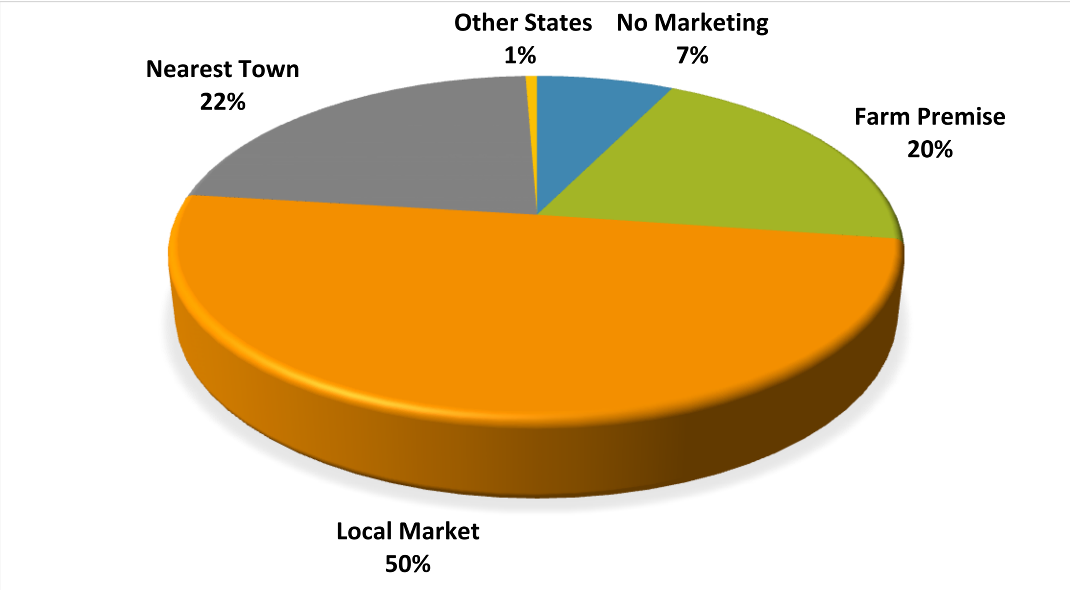
Figure 6.5 depicts the major markets for greenhouse vegetables. 51 percent of greenhouse farmers sold their products in local markets, 22 percent on farm premises, 19 percent in nearby towns, and one percent exported their products to other states. However, seven percent of farmers did not sell their produce. They used the products for personal consumption or as free gifts to friends and relatives. In other words, 73 percent of farmers sold their products on-site or at local markets.

6.7.2 Price of Greenhouse Crops in Different Markets

In order to increase earnings, it is essential to secure better prices for the goods. Therefore, it is essential to look into which markets pay the best prices to farmers. Below is a diagram showing how farmers feel about getting paid more for their greenhouse produce.

Figure 6.6

Higher Price Earning Markets



Source: Primary Data

Figure 6.6 illustrates that 50 percent of farmers obtained better prices for their products in local markets, while 22 percent experienced this in the nearest town, and 20 percent on their farm premises. Consequently, a majority of farmers (70%) opted to sell their products either at local markets or directly on their farm premises.

Table 6.15

Markets where the Highest Prices Fetch Different Sizes of Greenhouses

SL No	Size of GH	Marketing Places					
		No Marketing	Farm Premises	Local Market	Nearest Town	Other states	Total
1	Very Small (Upto100 sq. m)	52.63	42.11	5.26	0.00	0.00	100.00
2	Small (101 - 300 sq. m)	0.00	36.36	45.45	18.18	0.00	100.00
3	Medium (301-500 sq. m)	0.00	17.98	58.43	23.60	0.00	100.00
4	Large (501-1000 sq. m)	0.00	20.00	56.67	23.33	0.00	100.00
5	Very Large (Above 1000 sq. m)	0.00	6.25	43.75	43.75	6.25	100.00
All		6.06	21.21	49.70	22.42	0.61	100.00

Source: Primary Data

Table 6.15 shows the distribution of the highest prices earned by farmers from various market sources, classified according to farm size. The information is displayed in percentages. Notably, the majority (52.63%) of very small farms reported receiving no marketing benefits, while 42.11 percent earned higher prices on their farm premises and 5.26 percent in local marketplaces. The small farms reported earning the highest price from local markets, followed by farm premises (36.6%) and the nearest town (18.18%). Medium-sized farms received the greatest price on farm premises (17.98%), 58.43 percent in local markets, and 23.60 percent in the nearest town. Large and very large farms followed similar tendencies, with a growing reliance on local markets and the nearest town for the best pricing. Overall, most farmers (49.70%) found the best prices at local markets, while 21.21 percent found them on their farm premises and 22.42 percent in the nearest town. According to the research, local marketplaces have a considerable impact on determining the highest possible prices received by farmers of various sizes.

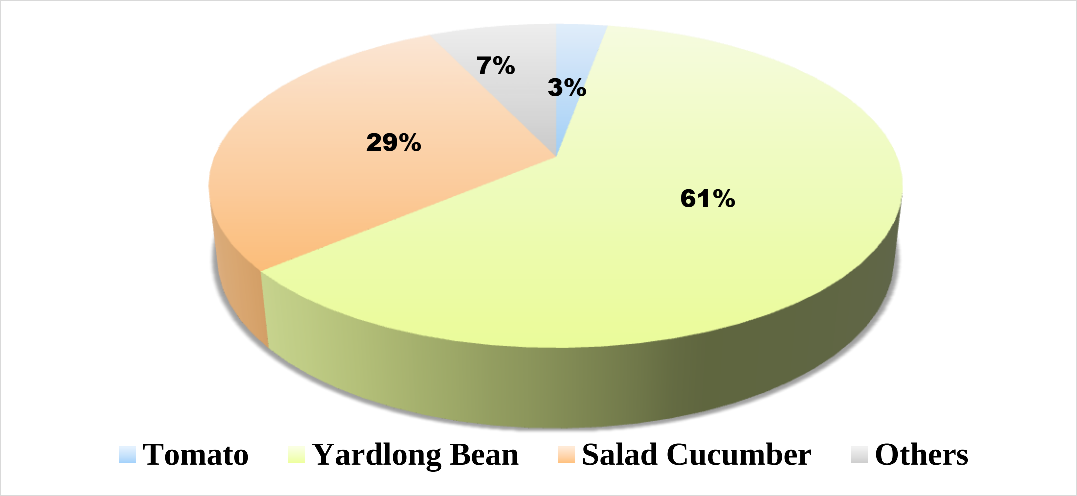
6.7.3 Most Wanted Crop in the Market

Greenhouses are used to raise a variety of vegetables. However, the market demand for these is different. There are products in high and low demand. It is critical to produce high-demand products in order to generate income. The figure below depicts the most wanted greenhouse vegetables in the market.

As seen in figure 6.7, yardlong beans and salad cucumber were the most popular greenhouse vegetable crops. Yardlong beans were the most desired crop, according to 61 percent of respondents, followed by salad cucumbers (29%). Only three percent voted for tomatoes, with the remaining three percent voted for other crops.

Figure 6.7

Most Wanted GH Crops in the Market



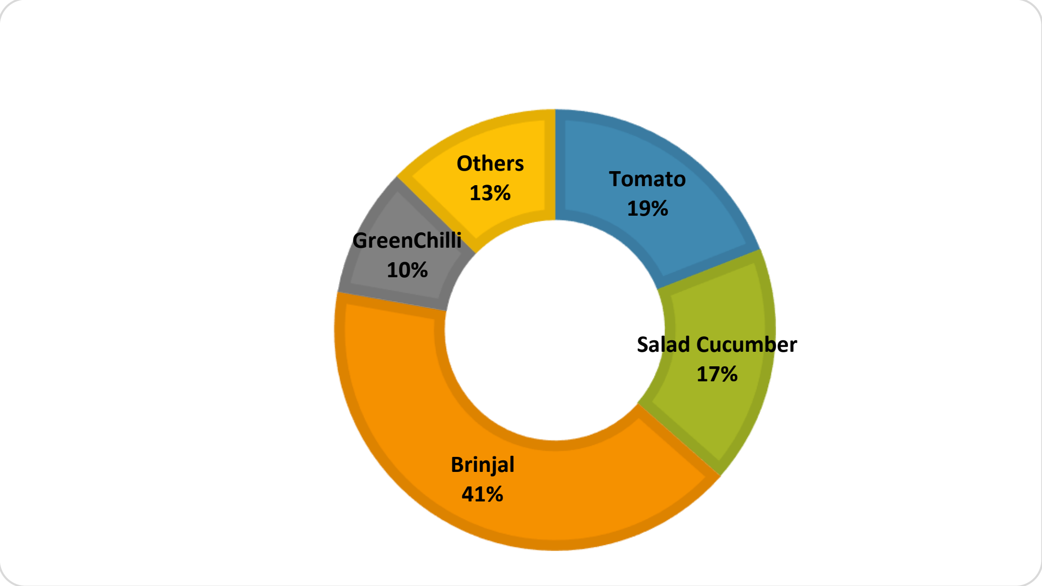
Source: Primary Data

6.7.4 Least Wanted Crop in the Market

It is just as crucial to produce more in-demand crops as it is to avoid producing insufficiently in-demand crops. This is especially true in high-cost agricultural endeavours like greenhouse farming. The figure below shows which crops were least desired on the market according to farmers' experiences.

Figure 6.8

Least Wanted GH Crop in the Market



Source: Primary Data

As shown in figure 6.8, according to 41 percent of farmers, brinjal was the least desired crop in the market, followed by tomato (19%), salad cucumber (17%), and green Chilli (10%). Other crops, according to 13 percent of farmers, were the least desired in the market.

6.8 Annual Revenue from Greenhouses

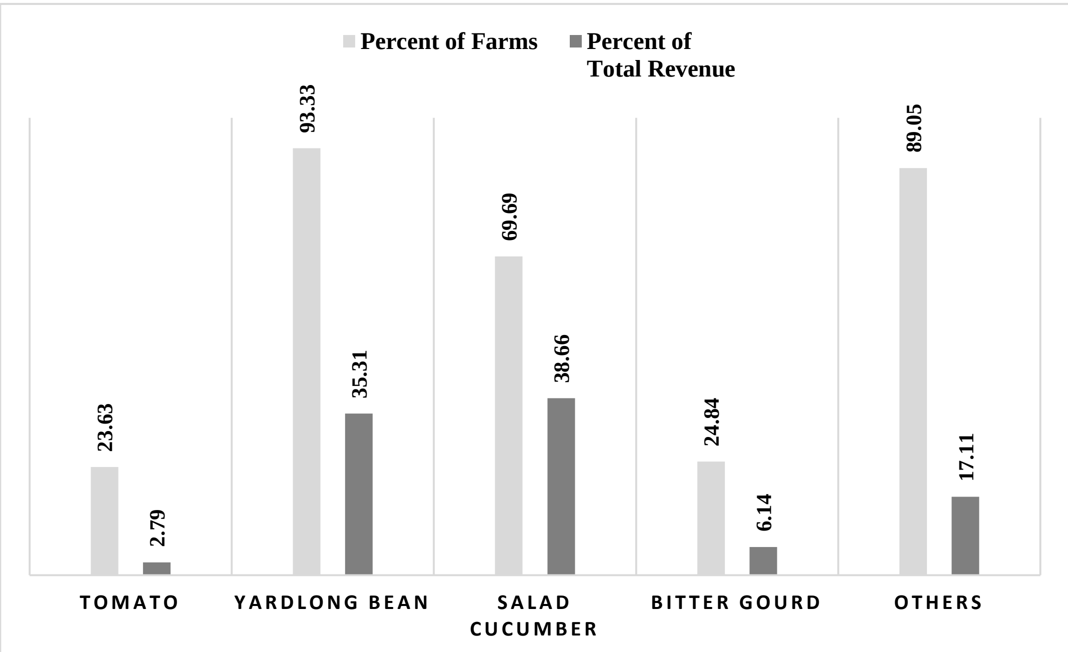
As stated earlier, there were a number of crops usually cultivated in greenhouses in Kerala. However, their proportions regarding both production and revenue generation were not equal. The following table and figure illustrate the revenue generated from the cultivation of various crops.

Table 6.16
Revenue from Different Crops

SL No	Crop	Number of Farmers	Revenue	
			Amount Rs	Proportion of Total Revenue
1	Tomato	39	867900	2.78
2	Capsicum	7	147900	0.48
3	Yard long Bean	154	10983600	35.30
4	Cabbage	11	194400	0.62
5	Cauliflower	8	171450	0.55
6	Salad Cucumber	115	12025500	38.65
7	Green chilli	27	709250	2.27
8	Spinach	31	1221300	3.9
9	Bitter gourd	41	1910320	6.14
10	Brinjal	24	278300	0.89
11	Other	39	2598730	8.35
Total			**31108650**	**100**

Source: Primary Data

Figure 6.9
Prominent GH Crops



Source: Primary Data

According to table 6.16 and figure 6.9, the annual revenue generated by the farmers from greenhouse vegetable cultivation was Rs. 3.11 crore. Salad cucumber was the most important greenhouse vegetable crop in terms of revenue generation in the state, followed by yardlong beans. Out of a total of 165 farms, 154 were growing the yardlong bean. They did, however, generate an annual revenue of Rs. 109,83600. On the other hand, 115 farmers produced salad cucumbers but earned Rs. 120,25500 in revenue. Salad cucumbers provided 38.65 percent of the total revenue generated in the year, while yardlong beans provided 35.30 percent. When these two crops were combined, they contributed 74 percent of the total revenue. As a result, in Kerala, greenhouse vegetable cultivation focuses on salad cucumbers and yardlong beans. The proportion of high-value crops such as capsicum, lettuce, and so on was negligible.

6.8.1 Annual Revenue across Various Sizes of Greenhouses

Total and average revenue are very important factors after costs to determine the economic viability of production activity. The amount of revenue each greenhouse operator received during the survey year is taken into consideration for analysis. The following table illustrates the average value of annual revenue and revenue per kilogramme of output for various sizes of greenhouses.

Table 6.17.1

Total Revenue and Average Revenue of Different Sizes of Greenhouses

SL No	Size of GH	Number	Annual Average Revenue Per GH Rs.	Annual average Revenue per kg of output Rs.
1	Very Small (Up to100 sq. m)	19	10597	44.45
2	Small (101 - 300 sq. m)	11	87427	63.76
3	Medium (301-500 sq. m)	89	160733	48.03
4	Large (501-1000 sq. m)	30	283866	47.78
5	Very Large (Above 1000 sq. m)	16	436281	38.9
All		165	187665	47.73

Source: Primary Data

Table 6.17.2

Hypothesis Test Summary

SL No	Null Hypothesis	Test	Significance	Decision
1	The distribution of average revenue per kg is the same across categories of size of farms	Independent Samples Kruskal-Wallis Test	0.055	Retained the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

Table 6.17.1 shows the mean value of total revenue and average revenue per kg of the output of various sizes of greenhouses. Accordingly, the average annual revenue of very small greenhouses was Rs. 10597 and it increased to Rs. 87427, Rs. 160733, Rs. 283866, and Rs. 436281 for small, medium, large, and very large greenhouses, respectively. Regarding revenue generated from one kilogram of output, the highest amount was secured by small greenhouses, followed by medium (Rs. 48.03) and large (Rs. 47.78). The least amount of average revenue per kg was secured by very large farms (Rs. 38.9). For all sized farms, the average revenue per kg was Rs. 47.73. However, as per table 6.17.2, this difference in average revenue was not statistically significant. In other words, there is no significant difference in the average revenue per kilogram of output for various sizes of greenhouses.

6.9 Annual Profit from Greenhouses

One of the primary goals of any economic endeavour is to make a respectable profit. High-tech farming in greenhouses, which involves a large investment, has the goal of making a decent profit to keep going. It is necessary to investigate the profitability of greenhouse vegetable farming in the state after a thorough examination of the costs and revenues of this operation.

6.9.1 Annual Profit Estimation

Profitability is critical for the long-term viability of any production activity, including farming. The difference between revenue and expenses is profit. Profit can be calculated from various angles. As previously indicated, the government typically provides substantial subsidies for greenhouse construction. This financial assistance helped the operators successfully run the business. But the economic viability of growing vegetables in greenhouses with and without subsidies and using different costing methods needs to be looked at.

6.9.2 Profit Estimation Without Subsidy

Here was consideration for both the government's and greenhouse operators' expenses. For the analysis, cost concepts A1, C2, and C3 were used to examine the profit of different greenhouses in detail.

6.9.3 Profit Based on Paid out Cost A1

As previously stated, cost A1 includes all paid-out costs such as annual fixed costs, hired labour costs, material costs, and interest on borrowed capital. Most greenhouse owners think that paid-out costs are the only costs, so it is important to look at how much money was made after these costs were taken into account.

Figure 6.10

Performance of GHs Based on A1 Cost

Source: Primary Data

Figure 6.10 shows that only 49 percent (81 numbers) of greenhouses were profitable based on annual A1 costs and revenue. During the survey period, the majority of the greenhouses (51%) were under loss. This fact reveals the lack of profit generated by Kerala's greenhouse vegetable producers.

Table 6.18 depicts the proportion of profitable farms and nonprofitable farms in various greenhouse size categories. Large farms had the highest proportion of profit-makers (63.3%), followed by small (54.5%) and medium (48.1%) farms. Only 25 percent of the very large farms made a profit. The probability of the $\chi 2$ test at 4 degrees of freedom was 0.176, indicating that there was no association between the proportion of profit-makers and greenhouse size categories.

Table 6.18
Profit or Loss per sq. m area across Size Categories of GHs (Cost A1)

Sl No	Size Category	Profit Earning	Loss Making	Total	Test
1	Very Small (Up to100 sq. m)	9 (47.4)	10 (52.6)	19	**Pearson $\chi 2(4)$ = 0.326 p = 0.176**
2	Small (101 - 300 sq. m)	6 (54.5)	5 (45.5)	11	
3	Medium (301-500 sq. m)	43 (48.3)	46 (51.7)	89	
4	Large (501-1000 sq. m)	19 (63.3)	11 (36.7)	30	
5	Very Large (Above 1000 sq. m)	4 (25)	12 (75)	16	
All		81 (49.1)	84 (50.9)	165	

Source: Primary Data. Values in parenthesis are percentages of the row total

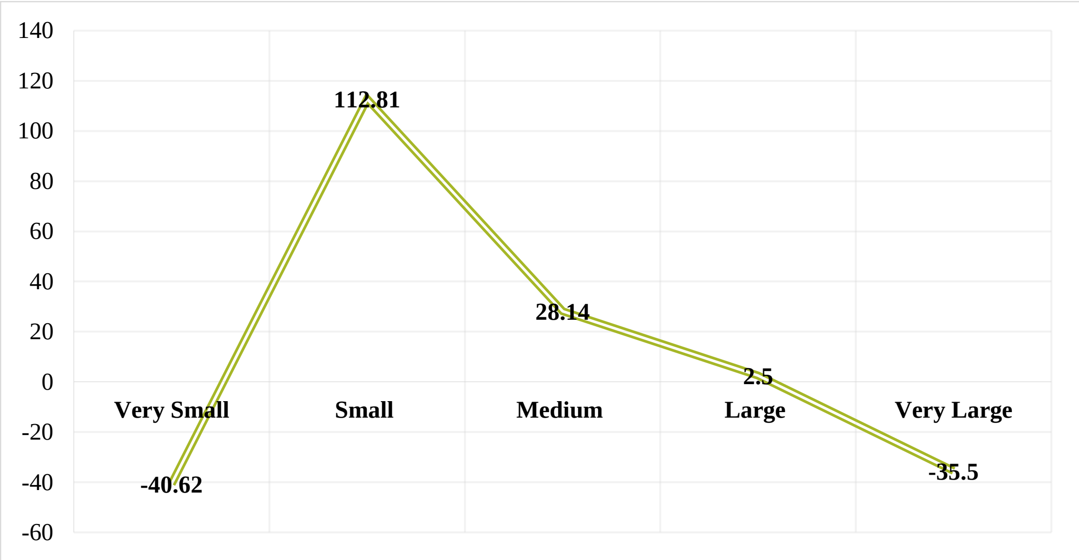
Table 6.19
Average Revenue, Average Cost (A1) and Average Profit per sq. m of the area of Various Sizes of Greenhouses without Subsidy

SL No	Size of GH	Average Revenue Per sq. m Rs.	Average Cost A1 Per sq. m Rs.	Average Profit per sq. m. Rs.	Minimum Profit Per sq. m Rs.	Maximum Profit Per sq. m Rs.
1	Very Small (Upto100 sq. m)	302	342.5	-40.62	-495	250
2	Small (101 - 300 sq. m)	397	284.5	112.81	-218	652
3	Medium (301-500 sq. m)	395	367	28.14	-425	830
4	Large (501-1000 sq. m)	344	341.5	2.5	-1152	380
5	Very Large (Above 1000 sq. m)	244	279.5	-35.5	-212	157
All		360.5	345.5	15	-1152	830

Source: Primary Data

Figure 6.11

Annual Profit per sq. m Area



Source: Primary Data

Table 6.19 and figure 6.11 illustrate average revenue, average cost (A1), and average profit per sq. m. area for various sizes of greenhouses. Moreover, the minimum and maximum values of profit are also visible. Accordingly, small, medium, and large greenhouses earned a profit, while two extremes, such as very small and very large, incurred a loss. For all-size greenhouses, Rs. 15 was the average profit earned from one sq. m. The highest average loss-incurring farm belonged to large greenhouses, while the highest average profit-earning farm belonged to medium greenhouses.

Table 6.20 shows the average revenue, cost, and profit for growing one kilogramme of vegetables in a greenhouse. As a result, for all greenhouse sizes, a loss of Rs. 13.86 was incurred by producing one kg of output. The average profit for all size categories was negative, despite the size-wise difference being visible. Small greenhouses suffered the greatest loss, then medium-sized and very-large greenhouses. In short, all greenhouse types were losing money when producing one kilogramme of vegetables. In other words, vegetable cultivation was not profitable in Kerala.

Table 6.20
Average Revenue, Average Cost (A1) and Average Profit per kg of the Output of Various Sizes of Greenhouses without Subsidy

SL No	Size of GH	Average Revenue Per Kg Rs.	Average Cost A1 Per Kg Rs.	Average Profit per kg Rs.
1	Very Small (Upto100 sq. m)	44.45	52.07	-7.62
2	Small (101 - 300 sq. m)	63.76	100.38	-36.61
3	Medium (301-500 sq. m)	48.03	63.59	-15.56
4	Large (501-1000 sq. m)	47.78	53.37	-5.58
5	Very Large (Above 1000 sq. m)	38.9	50.76	-11.86
All		47.73	61.6	-13.86

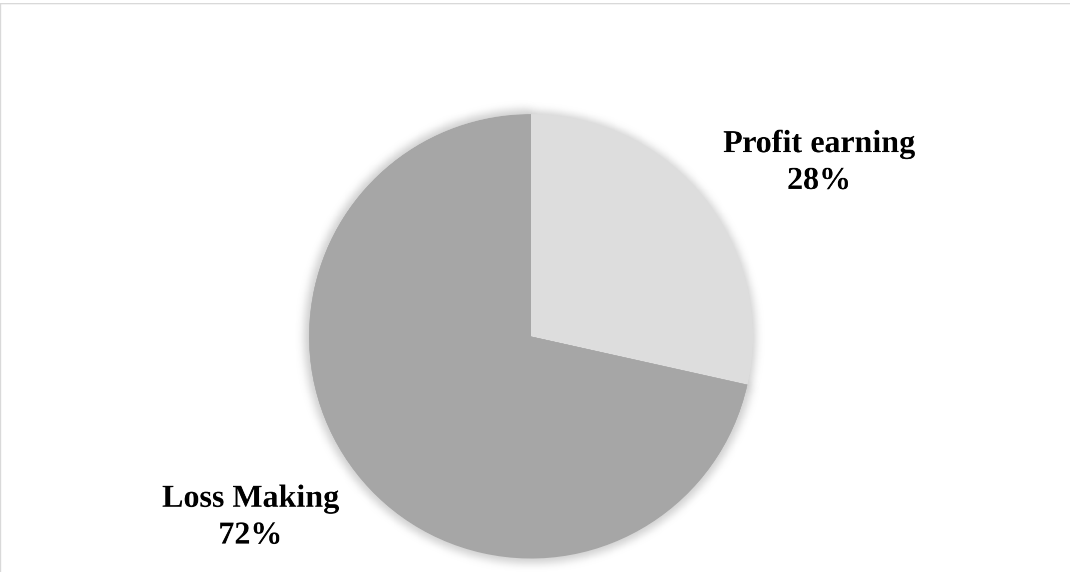
Source: Primary Data

6.9.4 Profit Based on C2 Cost

C2 costs include interest on one's own investment as well as the value of one's family and one's own work, in addition to the costs incurred. Given these costs, it is necessary to determine how many greenhouses were profitable.

Figure 6.12

Performance of GHs Based on C2 Cost



Source: Primary Data

Figure 6.12 demonstrates that just 28 percent of the greenhouse was profitable when the cost of C2 is taken into account. The remaining 72 percent of greenhouses were suffering losses. This unfortunate truth demonstrates the state's inability to generate wealth through greenhouse operations. Greenhouse farmers, like most other farmers, struggle to make a profit. A farm-size-wise analysis of the performance of the greenhouse farming activity is given in the following table.

Table 6.21

Average Revenue, Average Cost (C2) and Average Profit per sq. m of Various Sizes of Greenhouses without Subsidy

SL No	Size of GH	Average Revenue Per sq. m Rs.	Average Cost C2 Per sq. m Rs.	Average Profit per sq. m Rs.	Minimum Profit Per sq. m Rs.	Maximum Profit Per sq. m Rs.
1	Very Small (Upto100 sq. m)	302	680	-378	-1200	-63
2	Small (101 - 300 sq. m)	397	392	5	-434	545
3	Medium (301-500 sq. m)	395	460	-65	-605	742
4	Large (501-1000 sq. m)	344	430	-86	-1888	321
5	Very Large (Above 1000 sq. m)	244	334	90	-289	114
All		360	463	-103	-1888	742

Source: Primary Data

Table 6.21 illustrates the economic performance of different sizes of greenhouses on the basis of C2 cost per sq. m. area. Accordingly, only small and very large greenhouses made a profit, while the remaining very small, medium, and large greenhouses incurred losses. For very small greenhouses, the minimum and maximum values of profit were negative. It indicated that very small farms were not at all suitable to create wealth.

The relationship between greenhouse size and economic performance is shown in table 6.21. All of the very small greenhouses and 75 percent of the very large greenhouses suffered losses. The shares of loss-makers on small, medium, and large farms were 63.6 percent, 70.8 percent, and 56.7 percent, respectively. This association was also statistically significant, according to the Pearson $\chi2$ test.

Table 6.22

Profit or Loss per sq. m. Area across Size Categories of GHs (Cost C2)

Sl No	Size Category	Profit Earning	Loss Making	Total	Test
1	Very Small (Upto100 sq. m)	0 (0)	19 (100)	19	**Pearson $\chi2$ 11.269 df. 4 Prob. 0.024**
2	Small (101 - 300 sq. m)	4 (36.4)	7 (63.6)	11	
3	Medium (301-500 sq. m)	26 (29.2)	63 (70.8)	89	
4	Large (501-1000 sq. m)	17 (43.3)	13 (56.7)	30	
5	Very Large (Above 1000 sq. m)	4 (25)	12 (75)	16	
All		47 (28.5)	118 (71.5)	165	

Source: Primary Data. Values in parenthesis are percentages of the row total

Using the cost concept C2, table 6.23 shows the anticipated average profit of producing one kg of vegetables in greenhouses. As a result, vegetable cultivation was not economically viable in greenhouses of any size. The cost of producing one kilogramme of vegetables in greenhouses was Rs. 35.6. Small greenhouses had the largest burden (Rs. 76.7), followed by very small greenhouses (Rs. 65.5). The losses were Rs. 32.6, Rs. 19.4, and Rs. 22 for medium, large, and very large greenhouses, respectively.

Table 6.23

Average Revenue, Average Cost (C2) and Average Profit per kg of the Output of Various Sizes of Greenhouses without Subsidy

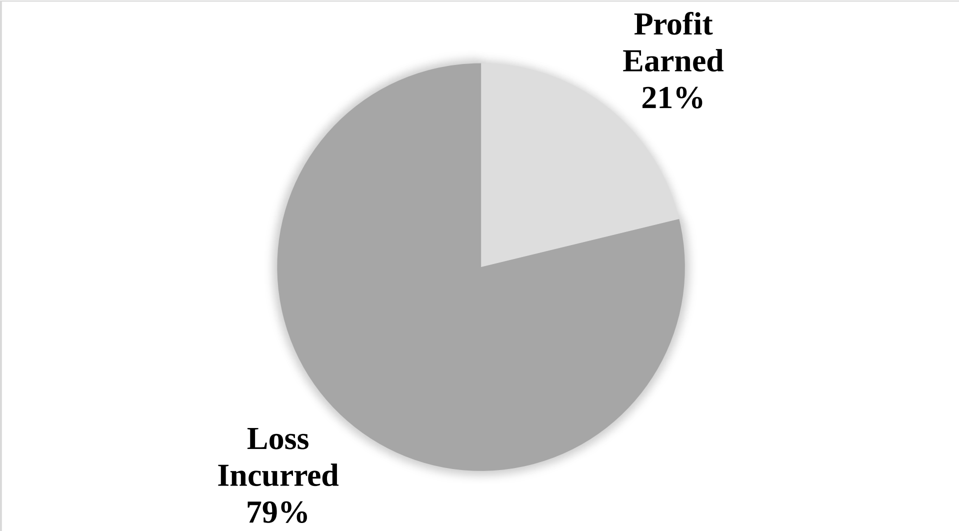
Sl No	Size of GH	Average Revenue Per Kg Rs.	Average Cost C2 Per Kg Rs.	Average Profit Per Kg Rs.
1] 1	Very Small (Upto100 sq. m)	44.45	107	-65.5
2	Small (101 - 300 sq. m)	63.76	140.46	-76.7
3	Medium (301-500 sq. m)	48.03	80.64	-32.6
4	Large (501-1000 sq. m)	47.78	67.25	-19.4
5	Very Large (Above 1000 sq. m)	38.9	60.95	-22
All		47.73	83.3	-35.6

Source: Primary Data

6.9.5 Profit Based on C3 Cost

Agriculture, like any other commercial activity, necessitates ongoing attention and organisation. Farmers, on the other hand, rarely think about such costs. The C3 cost, which includes management costs, can be used to assess the economic performance of greenhouse vegetable cultivation. Figure 6.13 depicts greenhouse performance in terms of C3 cost. Accordingly, only 21 percent of the greenhouses were profitable. The remaining 79 percent were in the loss. In other words, only one-fifth of the farms were profitable when all costs, including paid-out, imputed, and management expenses, were considered.

Figure 6.13
Performance of GHs Based on Cost C3



Source: Primary Data

Tables 6.24 and 6.25 depict the profit of different sizes of greenhouse farms from one sq. m. area and one kilogramme of output, respectively.

Table 6.24

Average Revenue, Average Cost (C3) and Average Profit per sq. m of Various Sizes of Greenhouses without Subsidy

SL No	Size of GH	Average Revenue Per sq. m Rs.	Average Cost C3 Per sq. m Rs.	Average Profit per sq. m Rs.	Minimum Profit Per sq. m Rs.	Maximum Profit Per sq. m Rs.
1	Very Small (Upto100 sq. m)	302	748.5	-446	-1345	-81.4
2	Small (101 - 300 sq. m)	397	431	-34	-502	505.6
3	Medium (301-500 sq. m)	395	506	-111	-677.6	696
4	Large (501-1000 sq. m)	344	473.6	-129.6	-2108	289
5	Very Large (Above 1000 sq. m)	244	367.8	-123.8	-338	95.7
All		360	509.74	-149.7	-2108	696

Source: Primary Data

Table 6.25
Average Revenue, Average Cost (C3) and Average Profit per kg of the Output of Various Sizes of Greenhouses without Subsidy

SL No	Size of GH	Average Revenue Per kg Rs.	Average Cost C3 Per kg Rs.	Average Profit Per kg Rs.
1	Very Small (Upto100 sq. m)	44.45	117.7	-73
2	Small (101 - 300 sq. m)	63.76	154.5	-90.7
3	Medium (301-500 sq. m)	48.03	88.7	-40.6
4	Large (501-1000 sq. m)	47.78	73.9	-26
5	Very Large (Above 1000 sq. m)	38.9	67	-28
All		47.73	91.7	-43.9

Source: Primary Data

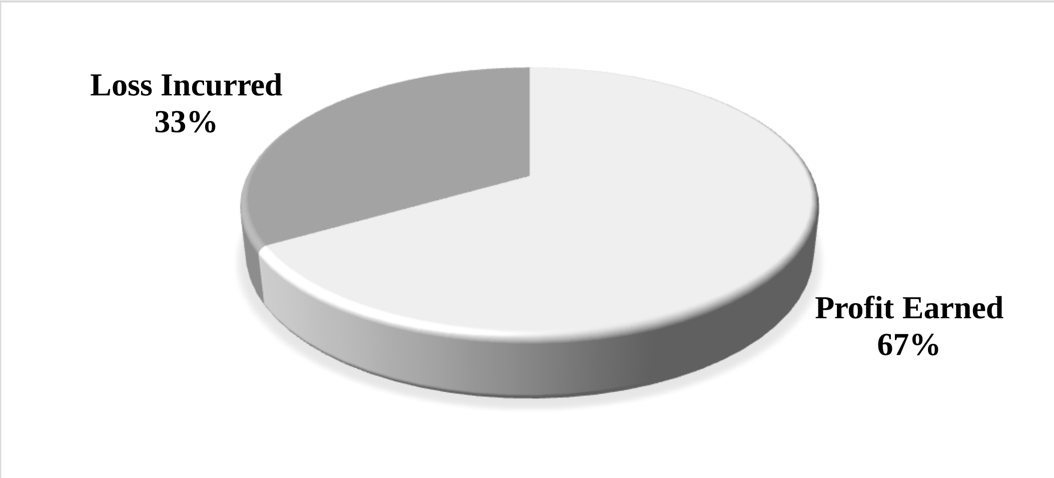
Farmers lost Rs. 149.7 per sq. m. area from the growing of vegetables in greenhouses, according to table 6.24. Very small farms lost the most money (Rs. 446), followed by large (Rs.129.6) and very large farms (Rs.123.8). The highest losses incurred by farms belonged to large farms followed by very small farms. According to table 6.25, for producing one kilogramme of vegetables, all farms lost an average of Rs. 43.9. Small farms had the highest (Rs. 90.7), followed by very small (Rs. 73) and medium (Rs. 40.6). Large and very large farms suffered relatively minor losses. In short, when cost C3 was taken into account, all sizes of greenhouses experienced losses in both area and quantity of output.

6.10 Profit Estimation with Subsidy

Here, it took into account the expenses that greenhouse owners alone bear. Just like in the earlier cases, cost concepts A1, C2, and C3 were used to examine the profit of different greenhouses in detail.

Figure 6.14

Performance of GHs (Cost A1 with Subsidy)



Source: Primary Data

Figure 6.14 demonstrates that, after subtracting the subsidy from construction costs, 67 percent of greenhouses in the survey year produced a profit based on cost A1. Only 49 percent of greenhouses were profitable if the subsidy was not taken into consideration, according to the earlier finding. In other words, if only private spending was considered, 18 percent more greenhouses would generate a profit. Despite government subsidies, however, 33 percent of the greenhouses were running at a loss.

The number of profit-making and loss-making greenhouses is shown in table 6.26. Accordingly, 66.7 percent of greenhouses of all sizes made a profit. Large greenhouses had the highest share of profit earners, followed by very small and medium greenhouses. On the other hand, very large greenhouses had the highest proportion of losses, followed by small greenhouses. But there was no link between the size of the greenhouse and the proportion of profit or loss made.

Table 6.26

Profit or Loss per sq. m. across Size Categories of GHs (Cost A1 with subsidy)

Sl No	Size Category	Profit Earned	Loss Incurred	Total	Test
1	Very Small (Upto100 sq. m)	14 (73.7)	5 (28.3)	19	Pearson χ^2 Value: 5.60 df. 4 Prob. 0.231
2	Small (101 - 300 sq. m)	7 (63.6)	4 (36.4)	11	
3	Medium (301-500 sq. m)	59 (66.3)	30 (33.7)	89	
4	Large (501-1000 sq. m)	23 (76.7)	7 (23.3)	30	
5	Very Large (Above 1000 sq. m)	7 (43.8)	9 (56.2)	16	
All		110 (66.7)	55 (33.3)	165	

Source: Primary Data Values in parenthesis are percentages of the row total

Table 6.27
Average Revenue, Average Cost (A1) and Average Profit per sq. m of Various Sizes of Greenhouses with Subsidy

SL No	Size of GH	Average Revenue Per sq. m Rs.	Average Cost A1 Per sq. m Rs.	Average Profit per sq. m Rs.	Minimum Profit Per sq. m Rs.	Maximum Profit Per sq. m Rs.
1	Very Small (Upto100 sq. m)	302	235.95	66.37	-279	395
2	Small (101 - 300 sq. m)	397	248.6	148.69	-200	685
3	Medium (301-500 sq. m)	395	298.93	96.33	-597	918
4	Large (501-1000 sq. m)	344	273.23	70.79	-1103	480
5	Very Large (Above 1000 sq. m)	244	225.23	18.82	-163	215
All		360.5	276	84.21	-1103	918

Source: Primary Data

Table 6.27 shows that if only paid-out costs were included, all sizes of greenhouses secured an average profit per sq. m. All greenhouse categories made an average annual profit of Rs. 84.21 per sq. m. With the exception of small farms, the average profit decreased as farm size increased. The large farms suffered the most losses, followed by the middle farms. Medium-sized farms had the highest profit margins, followed by small farms.

Table 6.28
Average Revenue, Average Cost (A1) and Average Profit per kg of the Output of Various Sizes of Greenhouses with Subsidy

SL No	Size of GH	Average Revenue Per Kg Rs.	Average Cost A1 Per Kg Rs.	Average Profit per Kg Rs.
1	Very Small (Upto100 sq. m)	44.45	35.19	9.26
2	Small (101 - 300 sq. m)	63.76	89.14	-25.37
3	Medium (301-500 sq. m)	48.03	52.67	-4.64
4	Large (501-1000 sq. m)	47.78	42.43	5.35
5	Very Large (Above 1000 sq. m)	38.9	39.01	-0.11
All		47.73	49.88	-2.15

Source: Primary Data

The average profit earned from one kilogramme of greenhouse vegetable output is shown in table 6.28. Accordingly, greenhouse producers lost Rs. 2.15 for each kilogramme of vegetables produced. Small greenhouses suffered the most losses, followed by medium greenhouses. Very small farms made Rs. 9.26 per kilogramme of output, whereas large farms made Rs. 5.35. A loss of Rs. 0.11 was suffered by the very large farms.

Table 6.29 shows the annual profit or loss made by various sizes of greenhouses. The 110 profit-earning greenhouses earned a total profit of Rs. 10269657, while the 55 loss-making greenhouses lost a total of Rs. 3841781. During the survey year, all greenhouses together made a net profit of Rs. 6427876. The net gains of various greenhouse sizes were Rs. 40410, Rs. 377200, Rs. 3709000, Rs. 1853057, and Rs.

448209, respectively, for very small, small, medium, large, and very large greenhouses.

Table 6.29
Annual Profit Earned or Loss Incurred by Various Sizes of GHs
(A1 Cost with Subsidy)

SL No	Size of GH	Profit Earned		Loss Incurred		Net Profit
		Number	Amount Rs.	Number	Amount Rs.	Amount Rs.
1	Very Small (Upto100 sq. m)	14	79250	5	38840	40410
2	Small (101 - 300 sq. m)	7	453700	4	76500	377200
3	Medium (301-500 sq. m)	59	5091550	30	1382550	3709000
4	Large (501-1000 sq. m)	23	3132057	7	1279000	1853057
5	Very Large (Above 1000 sq. m)	7	1513100	9	1064891	448209
All		110	10269657	55	3841781	6427876

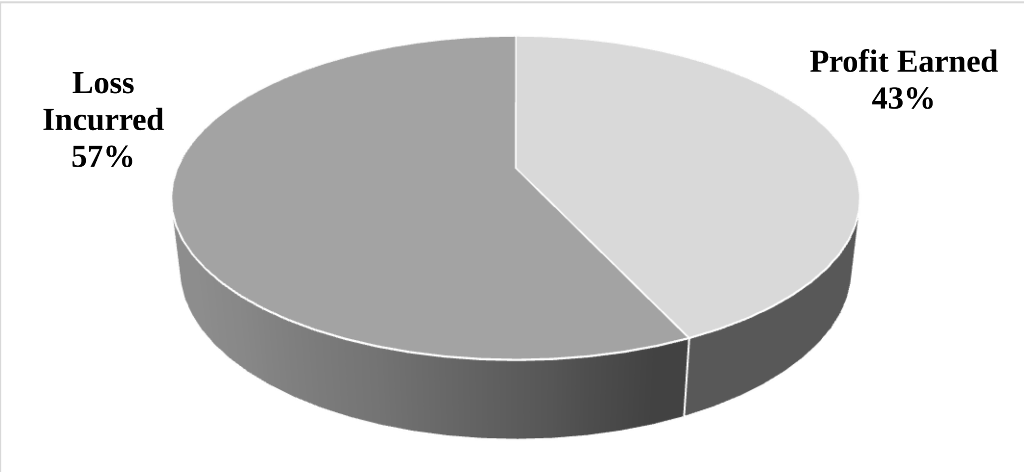
Source: Primary Data

6.10.1 Profit Based on C2 Cost with Subsidy

C2 costs include interest on one's own investment as well as the value of one's family and one's own work, in addition to the paid-out costs incurred. C2 cost-based profitability without adjusting subsidies was discussed earlier. Then it is necessary to analyse the same after deducting subsidies received by the farmers from the government. Figure 6.15 depicts the proportion of profit earned and loss incurred by greenhouses. Only 43 percent (71 numbers) of the total greenhouses made a profit, while the remaining majority (57%) lost money in the state.

Figure 6.15

Performance of GHs (C2 Cost with Subsidy)



Source: Primary Data

It is vital to determine whether the profitability of various greenhouse sizes is comparable. The following table shows the percentage of greenhouses of various sizes that earned a profit or loss.

Table 6.30
Profit or Loss Across Size Categories of GHs (Cost C2 with subsidy)

Sl No	Size Category	Profit Earning	Loss Making	Total	Test
1	Very Small (Upto100 sq. m)	2 (10.5)	17 (89.5)	19	Pearson $\chi^2(4) = 19.261$ $P < 0.001$
2	Small (101 - 300 sq. m)	5 (45.5)	6 (54.5)	11	
3	Medium (301-500 sq. m)	39 (43.8)	50 (56.2)	89	
4	Large (501-1000 sq. m)	21 (70)	9 (30)	30	
5	Very Large (Above 1000 sq. m)	4 (25)	12 (75)	16	
All		71 (43)	94 (57)	165	

Source: Primary Data. Values in parenthesis are percentages of the row total

Table 6.30 shows that large greenhouses (70%) had the highest share of profit earners, followed by small (45.5%) and medium (43.8%) greenhouses. On the other hand, very small greenhouses (89.5%) and very large greenhouses (75%), had the highest proportion of losers. According to previous statements, all very small, 63.6 percent of small, 70.8 percent of medium, 56.7 percent of large, and 75 percent of very large greenhouses would experience a loss without government assistance. Also, there was a clear link between the size of the farm and how likely it was to make a profit, as the Pearson $\chi 2$ test probability was less than 0.05.

Table 6.31
Average Revenue, Average Cost (C2), and Average Profit per sq. m Area of Various Sizes of Greenhouses with Subsidy

SL No	Size of GH	Average Revenue Per sq. m Rs.	Average Cost C2 Per sq. m Rs.	Average Profit Per sq. m Rs.	Minimum Profit Per sq. m Rs.	Maximum Profit Per sq. m Rs.
1	Very Small (Upto100 sq. m)	302	573	-271	-900	120
2	Small (101 - 300 sq. m)	397	356	40.9	-434	578
3	Medium (301-500 sq. m)	395	385	10.6	-518	829
4	Large (501-1000 sq. m)	344	362	-18	-1834	422
5	Very Large (Above 1000 sq. m)	244	279	-35	-239	152
All		360.5	391	-29.8	-1838	829

Source: Primary Data

The profitability of a square metre of greenhouse vegetable cultivation is illustrated in table 6.31. Accordingly, for all-sized greenhouses, it was not profitable to raise vegetables as it incurred a loss of Rs. 29.8 per sq. m. area. However, there was variation in profitability among different-sized greenhouses. Small and medium greenhouses made an average profit of Rs. 40.9 and Rs. 10.6, respectively, whereas very small, large, and very large greenhouses lost an average of Rs. 271, Rs. 18, and

Rs. 35 per sq. m. Large greenhouses incurred the biggest loss (Rs. 1834), while medium greenhouses reported the highest profit (Rs. 829).

Table 6.32

Average Revenue, Average Cost (C2), and Average Profit per kg of the output of Various Sizes of Greenhouses with Subsidy

SL No	Size of GH	Average Revenue Per kg Rs.	Average Cost C2 Per kg Rs.	Average Profit per kg Rs.
1	Very Small (Upto100 sq. m)	44.45	90.17	-45.7
2	Small (101 - 300 sq. m)	63.76	129.22	-65.46
3	Medium (301-500 sq. m)	48.03	69.72	-21.7
4	Large (501-1000 sq. m)	47.78	56.31	-8.53
5	Very Large (Above 1000 sq. m)	38.9	49.2	-10.3
All		47.73	71.62	-23.89

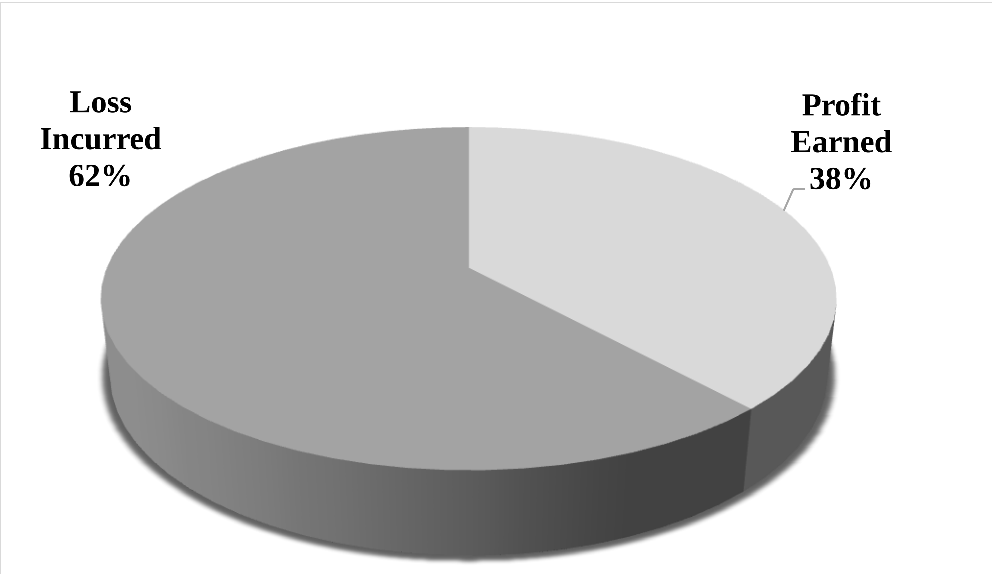
Source: Primary Data

Table 6.32 illustrates the average profitability of different sizes of greenhouses for producing one kg of vegetables. Accordingly, in all of these categories of greenhouses, vegetable production was not profitable. Producing one kg of vegetables in the greenhouses, on average, incurred a loss of Rs. 23.89. It was highest for small greenhouses (Rs. 65.46), then for very small greenhouses (Rs. 45.7). However, the intensity of loss was comparatively low for large and very large farms. In short, even in the presence of subsidies, greenhouse vegetable production was not profitable. Small greenhouses had revenue from the sale of vegetable seedlings in addition to the sale of vegetables. It might be the reason for earning a profit per sq. m. area while incurring a loss from vegetable production.

6.10.2 Profit Based on C3 Cost with Subsidy

As previously stated, C3 is a broad definition of cost that encompasses all forms of costs associated with farming, including paid-out costs, the imputed value of own resources, and managerial costs. When this cost is taken into account, the number of profitable greenhouses decreases. Only 38 percent of greenhouses made a profit, while the remaining 62 percent lost money, as shown in Figure 6.16. In other words, just one-third of the greenhouses were financially viable when all costs were included.

Figure 6.16
Performance of GHs (C3 Cost with Subsidy)



Source: Primary Data

The economic performance of different sizes of greenhouses is given in table 6.33. Accordingly, the proportion of profitable farms remained the same as in the case of cost C2 for very small and very large farms. However, in the cases of small, medium, and large farms, there were slight differences. The proportion of profitable farms declined to 36.4 percent, 40.4 percent, and 56.7 percent for small, medium, and large greenhouses, respectively. The highest decline in proportion happened on large farms. Furthermore, there was a statistically significant difference in the proportion of profitable greenhouse farms of various sizes.

Table 6.33

Profit or Loss Across Size Categories of GHs (Cost C3 with subsidy)

Sl No	Size Category	Profit Earning	Loss Making	Total	Test
1	Very Small (Upto100 sq. m)	2 (10.5)	17 (89.5)	19	Pearson χ^2 11.887 df. 4 Prob. 0.018
2	Small (101 - 300 sq. m)	4 (36.4)	7 (63.6)	11	
3	Medium (301-500 sq. m)	36 (40.4)	53 (59.6)	89	
4	Large (501-1000 sq. m)	17 (56.7)	13 (43.3)	30	
5	Very Large (Above 1000 sq. m)	4 (25)	12 (75)	16	
All		63 (38.2)	102 (61.8)	165	

Source: Primary Data. Values in parenthesis are percentages of the row total

Table 6.34
Average Revenue, Average Cost (C3), and Average Profit per sq. m Area of Various Sizes of Greenhouses with Subsidy

SL No	Size of GH	Average Revenue Per sq. m Rs.	Average Cost C3 Per sq. m Rs.	Average Profit per sq. m Rs.	Minimum Profit Per sq. m Rs.	Maximum Profit Per sq. m Rs.
1	Very Small (Upto100 sq. m)	302	630	-328	-1015.67	58.16
2	Small (101 - 300 sq. m)	397	392	5	-502.87	541.83
3	Medium (301-500 sq. m)	395	423	-28	-581	792.26
4	Large (501-1000 sq. m)	344	398	-54	-2053	399.64
5	Very Large (Above 1000 sq. m)	244	307	-63	-283.21	136.96
All		360.5	429	-68.5	-2053.84	792.26

Source: Primary Data

Table 6.34 shows the average profit of various greenhouse sizes from one sq. m. area when the C3 cost is taken into account. As a result, the average loss per sq. m. for all greenhouse sizes was Rs. 68.5. The greatest loss occurred in very small farms (Rs. 328), then in very large farms (Rs. 63), large farms (Rs. 54), and medium farms (Rs. 28). Small farms were the only type that made a profit, although a meagre one (Rs. 5).

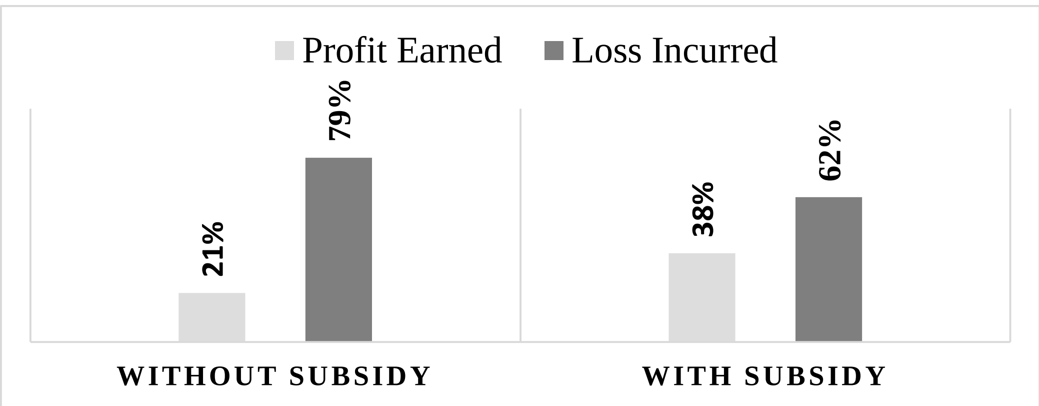
It has already been pointed out that all categories of greenhouses suffer an average loss per kilogramme of vegetable production when considering the cost of C2. Therefore, needless to say, greenhouses of all categories will be at a loss here as well, as management costs are added to them to reach C3 costs.

6.10.3 Role of Subsidy in Profit Earning in Greenhouse Cultivation

As previously stated, the government has subsidised greenhouse construction by up to 75 percent of the cost under certain conditions. Subsidies played a major role in deciding whether a greenhouse would win or lose. Figure 6.17 shows the annual performance of greenhouses with and without subsidies. Only 21 percent of greenhouses made a profit without subsidies, while 38 percent made a profit with subsidies. In other words, because the government subsidised greenhouse construction, 17 percent more greenhouses were profitable.

Figure 6.17

Performance of GHs with and without Subsidy (C3 Cost)



Source: Primary Data

Table 6.35

Hypothesis Test Summary

SL No	Null Hypothesis	Test	Significance	Decision
1	The distribution of different values across the performance of GHs without subsidy and with subsidy (C3 cost based) are equally likely for the specified categories	Related-Samples McNemar Test	0.000	Rejected the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

Table 6.35 illustrates the hypothesis test summary of the profit before and after the subsidy. Accordingly, the hypothesis that the distributions of profit before and after subsidies were equally likely was rejected at the significance level of 0.05. In other words, subsidies played a great role in bringing greenhouses into the category of profit-earners.

6.11 Overall Economic Performance of Greenhouse Vegetable Cultivation

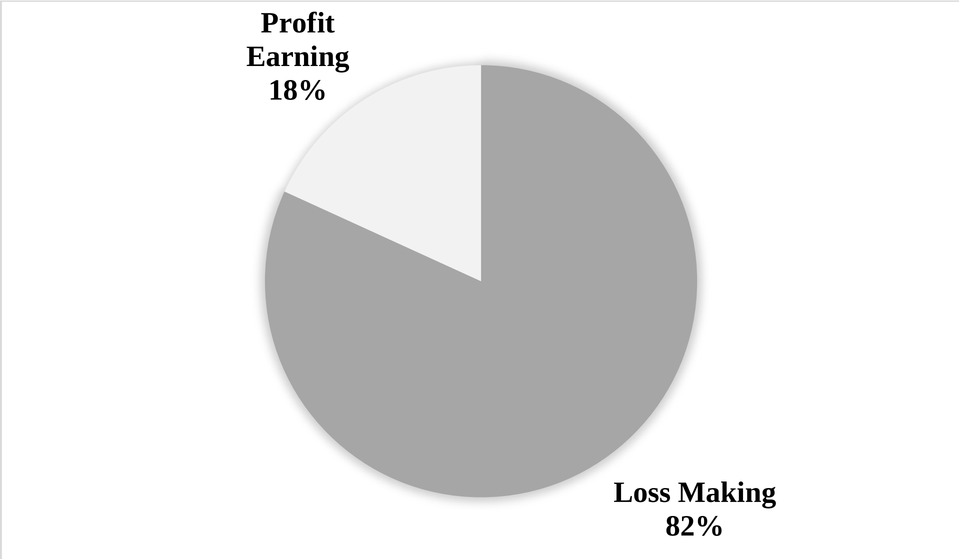
The entire profitability of farms was assessed from a broader viewpoint, taking into account costs and income from the beginning to the end of the survey year. This method provided a more sophisticated picture of the venture's financial health and long-term viability. Two scenarios were considered: one that included subsidies and one that did not. This enabled a thorough investigation of how external financial assistance affects the farms' long-term survival. The overall costs incurred and income generated over the full endeavour period enabled the detection of trends and patterns that would not have been obvious based just on annual numbers. This method also took into account the cumulative influence of elements such as market swings and operational initiatives, providing a more realistic picture of the venture's resilience and adaptability.

6.11.1 Performance of Greenhouses without Subsidy

Although greenhouse farming is a heavily subsidised activity, it is important to analyse how many of those can sustain themselves without government support. If the subsidy is not subtracted from the total cost, the number of greenhouses operating profitably is explained in the following figures:

Figure 6.18

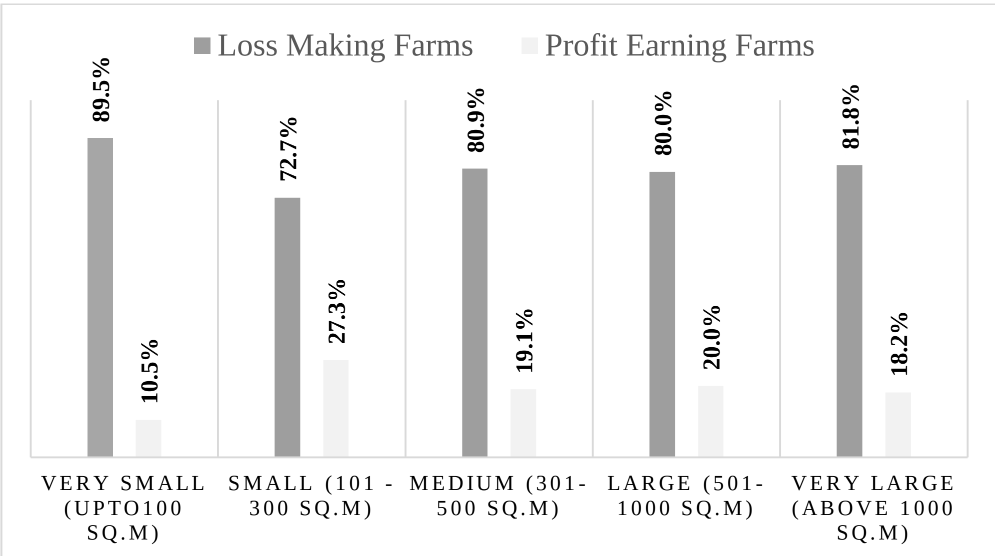
Profit-Earning and Loss-Incurring GHs (Cost C3)



Source: Primary Data

Figure 6.19

Size-wise Distribution of Profit-Earning and Loss-Incurring GHs without Subsidy



Source: Primary Data

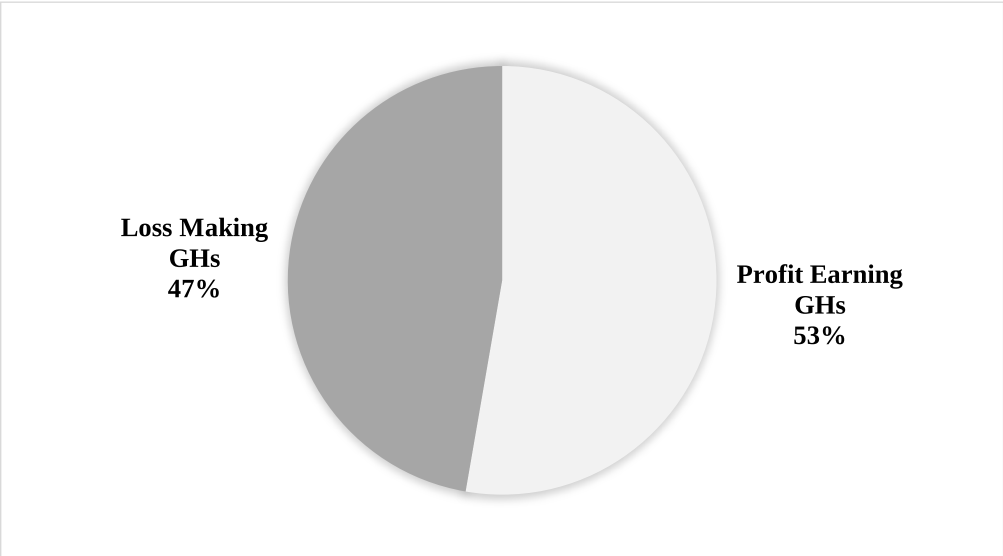
Figure 6.18 illustrates that only 18 percent of greenhouses were profitable, while the remaining 82 percent incurred losses. This emphasises the significance of government support in this endeavour. Figure 6.19 shows the variation in the proportion of profitable farms based on farm size. Accordingly, small farms had the highest share of profitable farms in the absence of subsidies (27.3%). The performance of medium (19.1%), large (20%), and very large (18.2%) farms was similar. In the absence of subsidies, very small farms had the lowest share of profitable farms.

6.11.2 Performance of Greenhouses with Subsidy

High-tech farming is a costly activity that involves the installation and supplementation of greenhouses. That is why farmers in general are reluctant to get into this activity. However, the sector is heavily subsidised by the central government through the NHM and the state government through the SHM. Subject to conditions, this would amount to approximately 75 percent of the total construction cost. Apart from this, an agricultural subsidy is also being provided to eligible farmers to cover other expenses. As a result, many farmers were ready to try this new farming method. The following is an analysis of the financial performance of greenhouses that have been operating this way for years.

Figure 6.20

Overall Performance of GHs with Subsidy

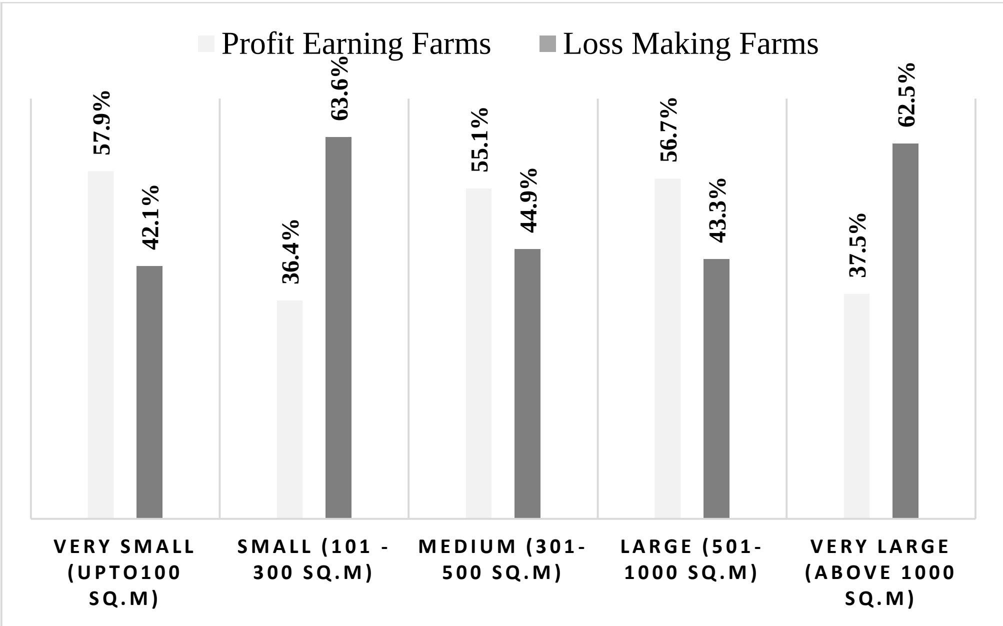


Source: Primary Data

Figure 6.21

Size-wise Distribution of Profit Earning and Loss incurring GHs

(Overall Performance)



Source: Primary Data

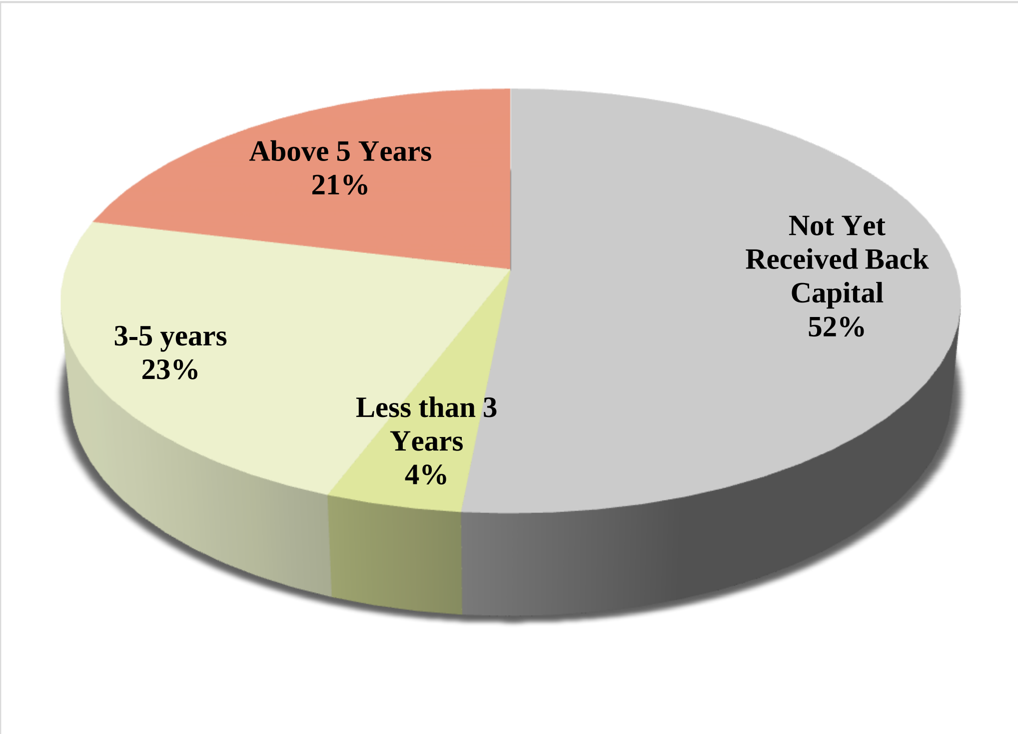
Figure 6.20 shows that 53 percent of greenhouses made a profit, while 47 percent lost money. In other words, around half of the greenhouses made a profit in the presence of subsidies. Figure 6.21 also depicts the profit earned or loss incurred by various sizes of GHs. As a result, very small farms (57.9%) had the highest proportion of profitable farms, followed by large farms (56.7%) and medium farms (55.1%). The performance of small and very large farms was nearly identical (36.4% and 37.5%, respectively). Even with hefty subsidies, just half of the greenhouses were profitable, according to these two figures.

6.11.3 Payback Period of Greenhouse Farms

One of the most important elements in determining an activity's economic sustainability is its payback period. It is a measure of how long it will take to recoup the money spent. Investors want to get their money back as soon as possible by generating revenue. Because the greenhouse vegetable producers' original investment was so large, they want to recoup their money as soon as possible. Only the subsidy deducted from the cost was taken into account when calculating the payback period. Figure 6.22 illustrates the nature of the payback period of greenhouse vegetable farms. As a result, the majority (52%) of farmers did not recoup their invested capital, while 4% had a payback period of less than three years, 23% had a payback period of three to five years, and the remaining 21% had a payback period of more than five years. In other words, it takes many years to recoup the money spent on greenhouse vegetable cultivation.

Figure 6.22

Payback Period of GH Farms



Source: Primary Data

Table 6.36.1
Payback Period of Various Sizes of Greenhouses

SL No	Size of GH	Not Yet Received Back Capital (%)	Less than 3 Years (%)	3 to 5 Years (%)	Above 5 Years (%)	Average Payback Period (Years)	Minimum Payback Period (Years)	Maximum Payback Period (Years)
1	Very Small	11 (57.9)	1 (5.3)	3 (15.8)	4 (21)	4.75	2.5	7
2	Small	6 (54.5)	0	4 (36.4)	1 (9.1)	3.4	3	5
3	Medium	48 (53.9)	4 (4.5)	19 (21.3)	18 (20.2)	4.32	2	7
4	Large	12 (40)	1 (3.3)	10 (33.3)	7 (23.3)	4.5	2.5	8
5	Very Large	8 (50)	1 (6.2)	2 (12.5)	5 (31.2)	4.87	2.5	7
All		85 (52)	7 (4.2	38 (23)	35 (21.2)	4.4	2	8

Source: Primary Data

Table 6.36.2

Hypothesis Test Summary

SL No	Null Hypothesis	Test	Significance	Decision
1	The distribution of payback period is the same across categories of size of farms	Independent Sample Kruskal-Wallis Test	0.609	Retained the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

Table 6.36.1 displays the average, minimum, and maximum payback periods for greenhouses of various sizes. Accordingly, 57.9 percent of very small farms did not recoup the money, while 5.3 percent took less than three years, 15.8 percent took three to five years, and 21 percent took more than five years. For very large farms, the figures were 50 percent, 6.2 percent, 12.5 percent, and 31.2 percent, respectively. The percentage of large farms that had not yet received their investment money was the lowest (40 percent). It is crucial to remember that even for those who got their money back, it took a long time (more than 5 years).

The average payback period for greenhouses of all sizes was 4.4 years. Very large farms accounted for 4.87 years, then very small farms (4.75 years), large farms (4.5 years), and medium farms (4.32 years). Small farms have the shortest payback period (3.4 years). The maximum payback period was reported for large farms (8 years), and the minimum payback period (2 years) was reported for medium farms. However, the difference in the average payback period of different-sized greenhouses was not statistically significant, as illustrated by table 6.36.2.

Farmers have engaged in greenhouse vegetable production as part-time or full-time occupations. As a result, the difference in payback periods between these two categories has to be investigated. According to table 6.37.1, 26 percent of full-time farmers and 56.11 percent of part-time farmers did not get back their investment. 30.8 percent of full-time farmers had a payback period of more than five years, while 34.6 percent had a payback period of three to five years. Part-time farmers accounted for 19.4 percent (more than 5 years) and 20.9 percent (3 to 5 years), respectively. Furthermore, the average payback period of full-time farmers was 4.42 years, while that of part-time farmers was 4.39 years. Even though they resemble equals, the distribution of payback periods between full-time and part-time categories was significantly different, as table 6.37.2 depicts.

Table 6.37.1

Payback Period of Full-time and Part-time Greenhouses Cultivation

SL No	Nature of Activity	Not Yet Received Back Capital (%)	Less than 3 Years (%)	3 to 5 Years (%)	Above 5 Years (%)	Average Payback Period (Years)	Minimum Payback Period (Years)	Maximum Payback Period (Years)
1	Full-time	7 (26.9)	2 (7.7)	9 (34.6)	8 (30.8)	4.42	2.5	7
2	Part-time	78 (56.11)	5 (3.6)	29 (20.9)	27 (19.4)	4.39	2	8
All		85 (52)	7 (4.2)	38 (23)	35 (21.2)	4.4	2	8

Source: Primary Data. Values in parenthesis are percentages of the row total

Table 6.37.2

Hypothesis Test Summary

	Null Hypothesis	Test	Significance	Decision
1	The distribution of payback period is the same across categories of full-time or part-time farmers	Independent Sample Mann-Whitney U Test	0.012	Rejected the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

On the farm, whether to produce a lot of crops or a single crop at a time for better economic performance is a contentious question. Farmers in greenhouses cultivated both a large number of crops and a small number of crops. The payback period for greenhouses that cultivated 1 to 3 crops, 4 to 5 crops, or more than 5 crops is shown in Table 6.38.1. Accordingly, 54.8 percent of farms that cultivated one to three crops at a time did not get their money back.

The same figures were 47.3 percent and 47.1 percent for farms that cultivated four to five crops and more than five crops, respectively. The proportion of greenhouses with a payback period of more than five years increased as the number of crops grown increased. The payback period was shortest for greenhouses that grew four to five crops. Then there were those that produced one to three crops and those that produced five or more crops. The maximum payback period was reported for the category of one to three crops. When the payback period is considered, it can be seen that producing four to five crops is optimal. However, the difference between the distribution of the payback period across the categories of the number of crops cultivated was not statistically significant, as table 6.38.2 illustrates.

Table 6.38.1

Payback Period & Number of Crops Cultivated

SL No	Number of Crops	Not Yet Received Back Capital (%)	Less than 3 Years (%)	3 to 5 Years (%)	Above 5 Years (%)	Average Payback Period (Years)	Minimum Payback Period (Years)	Maximum Payback Period (Years)
1	1 to 3	51 (54.8)	3 (3.2)	23 (24.7)	16 (17.2)	4.33	2	8
2	4 to 5	26 (47.3)	3 (5.5)	13 (23.6)	13 (23.6)	4.31	2	7
3	More than 5	8 (47.1)	1 (5.9)	2 (11.8)	6 (35.3)	4.88	2.5	6
All		85 (52)	7 (4.2)	38 (23)	35 (21.2))	4.4	2	8

Source: Primary Data

Table 6.38.2

Hypothesis Test Summary

SL No	Null Hypothesis	Test	Significance	Decision
1	The distribution of payback period is the same across categories of number of crops cultivated	Independent Samples Kruskal-Wallis Test	0.448	Retained the null hypothesis

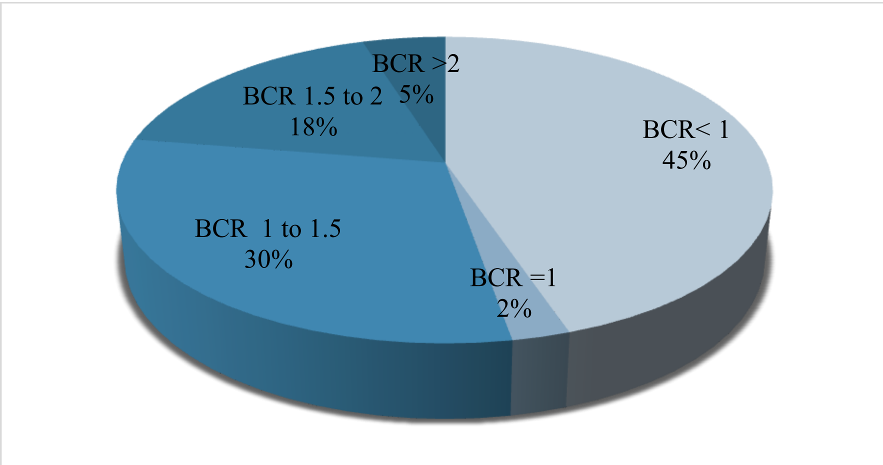
Asymptotic significances are displayed. The significance level is 0.05

6.11.4 Benefit-Cost Ratio (BCR) of Greenhouse Vegetable Farming

The BCR measures the relationship between a project's relative cost and benefits. If it is greater than one, the project is deemed profitable; if it is less than one, the project is deemed unprofitable. Because greenhouse vegetable cultivation necessitates a significant initial investment, it is critical to assess the extent of this venture's profitability. To calculate the BCR, both benefits and costs from the start of greenhouse cultivation until the survey year were considered. It is estimated by using the cost before and after the deduction of the subsidy separately. Figure 6.23 illustrates the BCR of greenhouses after the subsidy is deducted from the cost. As a result, 45 percent of the greenhouses had a BCR of less than one, indicating that their economic performance was inadequate. Two percent of them were in the position of getting only the cost. 30 percent of them earned satisfactory profits as their BCR was between 1 and 1.5. Another 18 percent of them succeeded in earning a better profit as their BCR was between 1.5 and 2. However, only five percent of greenhouses achieved high profits with BCRs greater than two. In other words, if only private costs were considered, 53 percent of greenhouses made a profit.

Figure 6.23

Benefit Cost Ratio with Subsidy



Source: Primary Data

Table 6.39.1 illustrates the BCR of different sizes of greenhouses. Accordingly, the highest proportion of nonprofitable farms was among small (63.6%) greenhouses, followed by very large farms (50%). On the other hand, the proportion of high BCR (above 2) farms was among large greenhouses (6.7%), followed by medium and very small farms. There was no one from very large greenhouses with a BCR higher than two. The majority of the greenhouses in all size categories belonged to the BCR of 1 to 1.5, except for small greenhouses. In short, most of the greenhouses from all size categories belonged to a moderate level of BCR between one and two. The average BCR was highest for large farms (1.2), followed by medium (1.13) and very large farms (1.01). The average BCR of very small and small farms was less than one. However, according to table 6.39.2, the difference in the distribution of BCR among various sizes of greenhouses was not statistically significant.

Table 6.39.1
Benefit-Cost Ratio with Subsidy of Various Sizes of Greenhouses

SL No	Size of GHs	BCR <1	BCR =1	BCR 1 to 1.5	BCR 1.5 to 2	BCR > 2	Average BCR
1	Very Small	8 (42.1)	0	10 (52.6)	0	1 (5.3)	0.96
2	Small	7 (63.6)	0	1 (9.1)	3 (27.3)	0	0.98
3	Medium	38 (42.7)	2 (2.2)	28 (31.5)	16 (18)	5 (5.6)	1.13
4	Large	13 (43.3)	0	8 (26.7)	7 (23.3)	2 (6.7)	1.20
5	Very Large	8 (50)	2 (12.5)	3 (18.8)	3 (18.8)	0	1.01
All		74 (44.8)	4 (2.4)	50 (30.3)	29 (17.6)	8 (4.8)	1.10

Source: Primary Data

Table 6.39.2
Hypothesis Test Summary

SL No	Null Hypothesis	Test	Significance	Decision
1	The distribution of BCR with subsidy is the same across categories of size of farms	Independent Sample Kruskal-Wallis Test	0.415	Retained the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

Table 6.40.1
Benefit-Cost Ratio with Subsidy of Full-time and Part-time Greenhouses Cultivation

SL No	Nature of Activity	BCR <1	BCR =1	BCR 1 to 1.5	BCR 1.5 to 2	BCR > 2	Average BCR
1	Full-time	12 (46.2)	0	8 (30.8)	5 (19.2)	1 (3.8)	1.20
2	Part-time	62 (44.6)	4 (2.9)	42 (30.2)	24 (17.3)	7 (5)	1.08
All		74 (44.8)	4 (2.4)	50 (30.3)	29 (17.6)	8 (4.8)	1.1

Source: Primary Data
Figures in parenthesis are percent of row total

Table 6.40.2

Hypothesis Test Summary

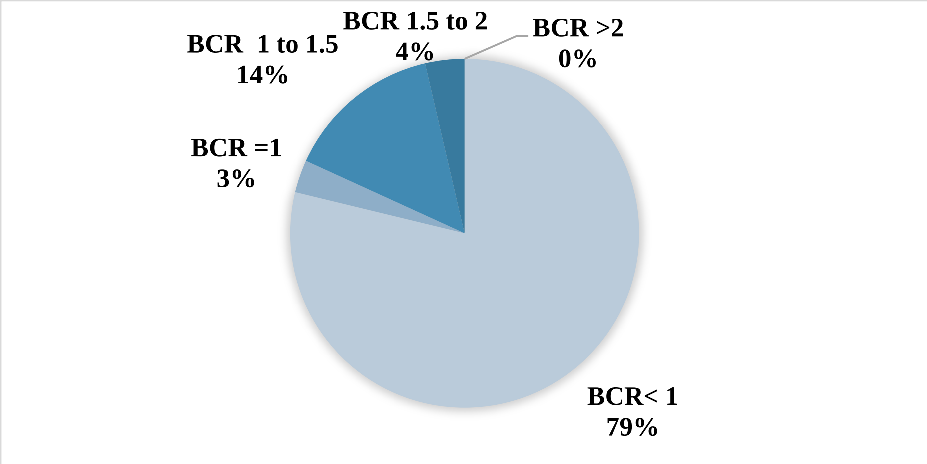
SL No	Null Hypothesis	Test	Significance	Decision
1	The distribution of BCR with subsidy is the same across categories of full-time and part-time farmers	Independent Samples Mann-Whitney U Test	0.323	Retained the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

Table 6.40.1 illustrates the BCR of full-time and part-time farmers' greenhouses. No significant difference is visible in the proportion of various levels of BCR for farmers doing greenhouse farming as a full-time activity or a part-time activity. Even though there was an 18 percent difference in average BCR between them, it was not statistically significant, as table 6.40.2 illustrates.

Figure 6.24 illustrates the economic performance of greenhouses without deducting subsidies from the cost. The costs incurred by the farmer as well as the government were taken into consideration for analysis. Accordingly, 79 percent of the greenhouses were incurring a loss as their BCR was less than 1. Another 3 percent was at breakeven, while 14 percent earned a satisfactory profit. Only 4 percent of the greenhouses earned a better profit as their BCR was between 1.5 and 2, while there were no farms with a BCR above 2. The facts explain the unsatisfactory performance of greenhouse vegetable farming in the absence of government subsidies.

Figure 6.24
Benefit Cost Ratio without Subsidy



Source: Primary Data

Table 6.41.1

Benefit-Cost Ratio without Subsidy of Various Sizes of Greenhouses

SL No	Size of GH	BCR <1	BCR =1	BCR 1 to 1.5	BCR 1.5 to 2	BCR > 2	Average BCR
1	Very Small	17 (89.5)	0	1 (5.3)	1 (5.3)	0	0.61
2	Small	8 (72.7)	0	0	3 (27.3)	0	0.80
3	Medium	67 (75.3)	5 (5.6)	15 (16.9)	2 (2.2)	0	0.733
4	Large	24 (80)	0	6 (20)	0	0	0.74
5	Very Large	14 (87.5)	0	2 (12.5)	0	0	0.635
All		130 (78.8)	5 (3)	24 (14.5)	6 (3.6)	0	0.715

Source: Primary Data

Very small GHs had the highest percentage of unprofitable units, followed by very large GHs, according to table 6.41.1. 72 percent of the small GHs had a BCR of less than one. No farms in any category earned a BCR above two. In the case of large and very large farms, the highest BCR was less than 1.5. Furthermore, the average

BCR of all size categories was less than one, indicating the heavy loss in greenhouse vegetable farming.

Table 6.42.1
Benefit-Cost Ratio with Subsidy of Full-time and Part-time Greenhouses Cultivation

SL No	Nature of Activity	BCR <1	BCR =1	BCR 1 to 1.5	BCR 1.5 to 2	BCR > 2	Average BCR
1	Full-time	22 (84.6)	1 (3.8)	2 (7.7)	1 (3.8)	0	0.759
2	Part-time	108 (77.7)	4 (2.9)	22 (15.8)	5 (3.6)	0	0.71
All		130 (78.8)	5 (3)	24 (14.5)	6 (3.6)	0	0.715

Source: Primary Data

Table 6.42.1 illustrates the BCR of full-time and part-time greenhouse vegetable farmers. Accordingly, 84.6 percent of full-time farmers and 77.7 percent of part-time farmers lost money from this activity. Even in the case of profit-makers, the BCR was less than two. The average BCR for both of these categories was less than one. It indicates the economic nonviability of greenhouse vegetable farming in the state of Kerala. It was subsidies given by the government that helped a few greenhouse farmers sustain this activity.

6.12 Major Factors Determining the Overall Profitability of GH Farms

Whether a GH farm earns profit or incurs loss depends upon many factors. To understand the relationship between various factors that determine the odds ratio of profit earned and loss incurred, logistic regression was used. The model was statistically significant [$\chi 2$ (12, N = 165) =119.508, p 0.001], suggesting that it could distinguish between those profit-earning and loss-incurred GHs. The model explained 84.1% (Nagelkerke R square) of the variance in the dependent variable and correctly classified 95.2% of cases. Further, the Hosmer-Lemeshow test shows the insignificance [$\chi 2$ (8, N = 165) = 0.996, p >.05]. As shown in Table 6.43 and figure 6.25, variables such as full-time activity, contracts with the merchants, better price, regular visits of agricultural officers, experience of farmers, and type of ventilation significantly contributed to the model.

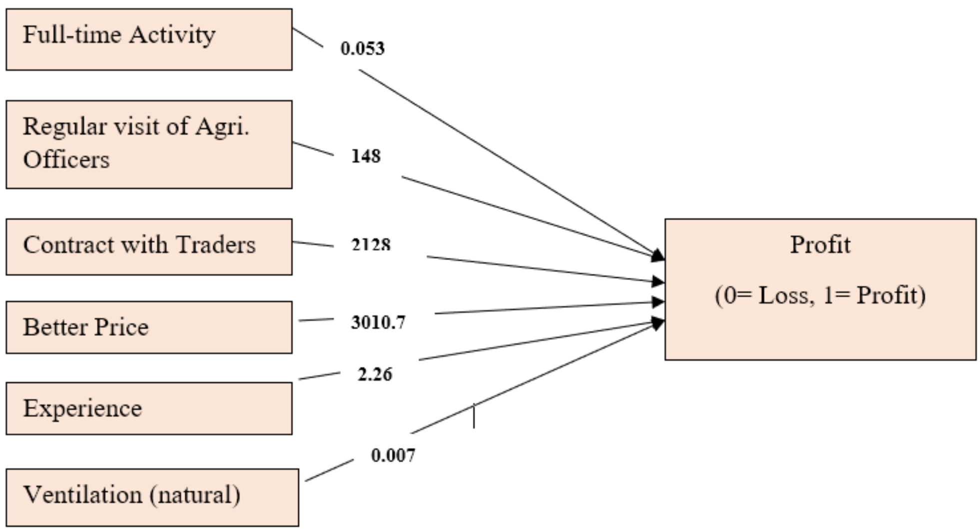
Table 6.43
Major Determents of Profit or Loss of GH Farms
(Variables in the Equation)

Variables		B	S.E.	Wald	df	p	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1[a]	Education	0.138	.207	.443	1	0.506	1.148	0.765	1.722
	Age	-0.074	0.07	1.744	1	0.187	0.928	0.831	1.037
	Full-time (1)	-2.939	1.37	4.610	1	0.032	0.053	0.004	0.774
	Regular Buyers (1)	-4.978	2.65	3.518	1	0.061	0.007	0.000	1.250
	Shade net (1)	4.843	2.56	3.580	1	0.058	126.839	0.840	19147.172
	Contract traders (1)	7.663	2.83	7.315	1	0.007	2128.12	8.246	549216.55
	Better price (1)	8.010	2.69	8.833	1	0.003	3010.70	15.294	592656.55
	Regular Visit_Agri_officers (1)	4.997	1.61	9.588	1	0.002	147.989	6.259	3498.813
	Experience_GH	0.813	0.33	6.028	1	0.014	2.254	1.178	4.313
	Number Crops	0.708	0.43	2.664	1	0.103	2.029	.868	4.746
	Labour Productivity	0.027	0.04	0.521	1	0.470	1.027	0.955	1.105
	Ventilation (1)	-4.897	2.00	5.983	1	0.014	0.007	0.000	0.378
	Constant	-12.81	4.67	7.537	1	0.006	0.000		

a. Variable(s) entered on step 1: Education, Age, Full_time, Regular_Buyers, Shade_net, Contract_traders, Better_price, Visit_Agri_officers, Experience_GH, Number_Crops, Labour_Productivity, Ventilation.

Figure: 6.25

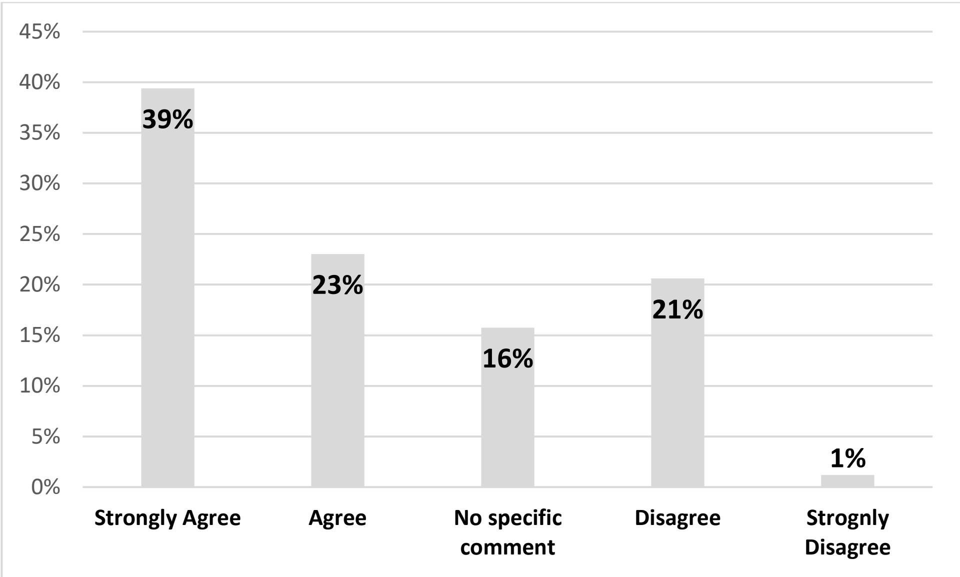
Significant Determinants of Profit or Loss of GH Farms



Contracts with vegetable traders, better prices earned according to the expectations of farmers, regular farm visits by agricultural officers, and farmers' experience in GH vegetable cultivation were all significant positive predictors of GH profit earning. For GHs entering into a contract, the possibility of profit was boosted by 2128 times. Better prices improved the likelihood of profit-earning by 3010 times. Regular visits by agricultural officers (at least once a month) increased the likelihood of profit-earning by 148 times. Similarly, one year of additional experience in GH vegetable growing increased the likelihood of profit earning by 2.254 times. Variables such as ventilation and full-time activity, on the other hand, were substantial negative predictors. When comparing naturally ventilated GHs to fan-ventilated counterparts, the likelihood of earning profit decreased by 0.007 times. Similarly, doing vegetable cultivation in GHs as a full-time activity reduced the likelihood of profitability by 0.053 times.

Labour productivity, regular buyers, farmers' age and education, number of crops, and usage of shade nets in GHs were not significant predictors of the model.

Figure 6.26
Farmers' Opinion on Non-Profitability of GH Vegetable Farming



Source: Primary Data

6.13. Opinion of Farmers on Unprofitability of Greenhouse Farming

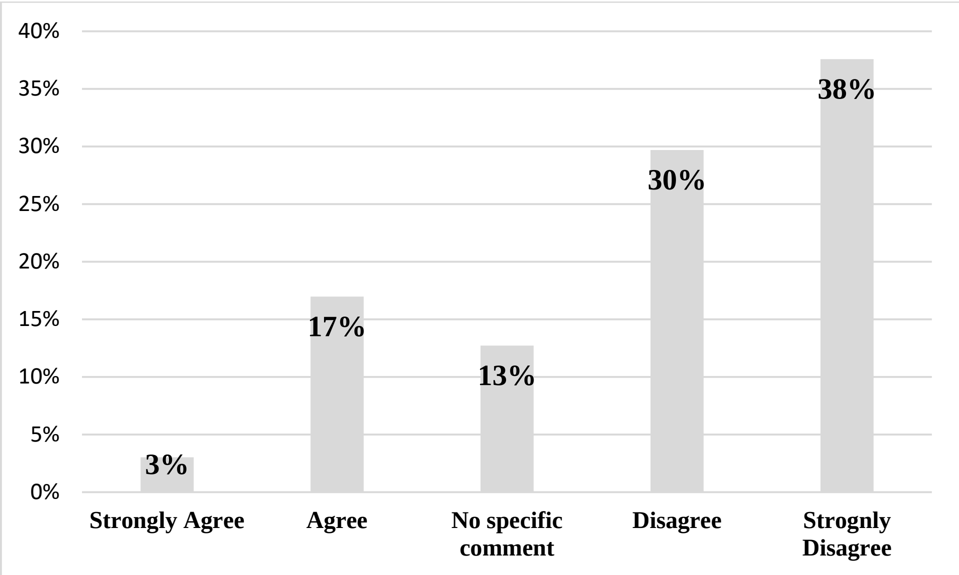
Figure 6.26 depicts how greenhouse vegetable growers feel about the sector's overall profitability. The majority of farmers (62 percent) agreed that growing vegetables in greenhouses was not a viable activity. Only 22 percent of them voiced a different opinion. Given that the average score was 3.78, all farmers concurred that growing vegetables in GH was not a profitable venture.

6.13.1 Does GH Vegetable Farming Provide Better Employment Opportunities to the Unemployed Youth: Farmers' Opinion

The provision of sufficient employment to the educated youth is one of the major challenges of the state of Kerala. To enhance employment opportunities, the agriculture sector also has to be modernized and equipped. Greenhouse vegetable cultivation might have such potential. Unfortunately, as the greenhouse technique followed in Kerala is a semi-tech activity, it failed to provide sufficient employment opportunities with a decent income to the educated youth. The following graph shows what greenhouse vegetable farmers think about the number of jobs the activity could create.

Figure 6.27

Farmers' Opinion on Better Employment Provision of GH Vegetable Farming



Source: Primary Data

As shown in figure 6.27, 68 percent of farmers disagreed with the claim that cultivating vegetables in greenhouses gives unemployed youngsters better employment opportunities. Only 20 percent of farmers endorsed the assertion. The average score of 2.2 indicated that farmers generally disagreed with the statement. As a result, educated youth did not have enough employment opportunities in greenhouse vegetable farming.

6.14 Conclusion

This chapter analysed the economic viability of high-tech vegetable cultivation in greenhouses in Kerala. Initially, the annual cost was estimated using the various concepts of costs, such as A1, B1, C2, and C3. These costs were estimated before and after the deduction of the subsidy given by the government to encourage the venture. The average cost per sq. m. area of greenhouses as well as per kg of vegetable output was estimated. The average cost of greenhouse vegetable cultivation in the state was found to be high. Then the annual revenue was estimated. As this activity failed to utilise the market potential, the average revenue per sq. m. area of greenhouses as well as per kg of vegetable output was high. On the basis of the estimated cost and revenue, the total annual profit and average profits of various sizes of greenhouses were estimated. Then it was found that the profit earned by them was not satisfactory, especially if the social cost was taken into consideration. The second part of this chapter estimates the overall economic performance of greenhouse vegetable cultivation. Just like the annual cost and revenue, analysis was done before and after the deduction of the subsidy from the cost. Tools such as the payback period and cost-benefit ratio were used to analyse the economic performance. As a result, 52 percent of the greenhouses did not recoup their investment. The majority (44%) of the remaining had a payback period of more than three years. Twenty-one percent of them had a payback period of more than five years. Small greenhouses had the shortest average payback period, while very large farms had the longest payback period. After deducting the subsidy, 45 percent of the greenhouses had a BCR of less than one, two percent had a BCR equal to one, 30 percent had a BCR of 1 to 1.5, and the remaining 23 percent had a BCR above 1.5. Prior to deducting the subsidy, the proportions were 79 percent, three percent, 18 percent, and zero percent, respectively. All these facts and figures proved that the economic viability of greenhouse vegetable cultivation in the state of Kerala was poor. The high cost and poor revenue generation were the major reasons for the poor economic performance of greenhouse vegetable cultivation in the state. Moreover, most of the farmers in the state agreed that the high-tech cultivation of vegetables in greenhouses was not a profitable activity and did not provide sufficient employment opportunities for the young, educated youth.

CHAPTER VII

TECHNO-ECONOMIC CONSTRAINTS OF HIGH-TECH FARMING

7.1 Introduction

Greenhouse technology in agriculture has the potential to help farmers adapt to unpredictable weather patterns caused by climate change. However, in Kerala, local farmers face challenges in successfully adopting and profiting from this method. The high cost of establishing and maintaining greenhouse systems, the lack of expertise and technical knowledge, and the scarcity of resources further exacerbate these challenges. Small-scale farmers, who make up a significant portion of Kerala's agricultural sector, may find it financially burdensome to invest in these technologies. Limited access to funds, appropriate technology, and training opportunities further hampers farmers' ability to adopt advanced technologies and techniques for successful greenhouse cultivation. Technical constraints include lack of technical expertise, inadequate knowledge about greenhouse management practices, and limited exposure to climate control and crop optimization. Economic constraints involve high upfront costs, uncertain returns, and difficulty in obtaining loans or financial assistance to invest in greenhouse infrastructure. Addressing these challenges requires providing farmers with affordable technologies, specialized training, and financial support.

7.2 Technical Constraints

The pest infestation, lack of information or relevant knowledge and skills, lack of government support or inadequate policies, lack of irrigation water, and lack of manpower or labour to work on farms are all technical limitations of greenhouse vegetable cultivation in the state. Technical constraints include a deficiency of certified seeds, public awareness and effective communication, suitable fertilisers and pesticides, the disposal of biodegradable and non-biodegradable agricultural wastes, and so on.

7.2.1 Pest Infestation

Pest protection is one of the major advantages of greenhouse vegetable farming. As a result, it is safer to consume foods that do not require as much cooking as vegetables because they do not contain pesticides. However, according to this study, this feature was not totally present in Kerala greenhouse farming. Figure 7.1 indicates that 62 percent of all greenhouses have been infested. Only 38 percent of greenhouses were able to successfully grow vegetables without being harmed by pests.

Figure 7.1

Extent of Insect Attack

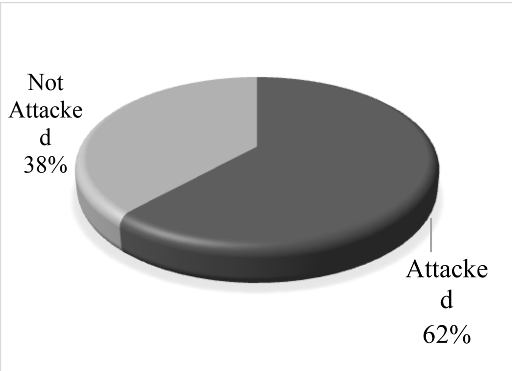
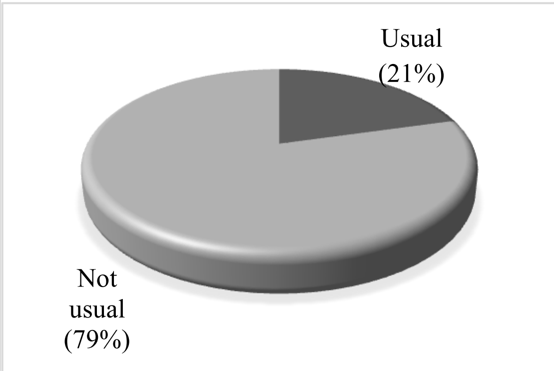


Figure 7.2

Intensity of Insect Attack



Source: Primary Data

However, as per figure 7.2, insect attack was usual in 21 percent of greenhouses, while the remaining 79 percent were attacked occasionally. In other words, the intensity of insect attacks was high on one-fifth of the greenhouse vegetable farms in the state. Table 7.1 illustrates the intensity of insect attacks on organic and non-organic farms. Accordingly, the intensity of pest attacks was comparatively higher on non-organic farms (33.3%) than on organic farms (17.1%). Crops were more protected against insect attack by the organic cultivation strategy than by the nonorganic cultivation strategy. Furthermore, this difference in intensity of infestation was statistically significant, as the p value of the Pearson $\chi 2$ test was less than 0.05.

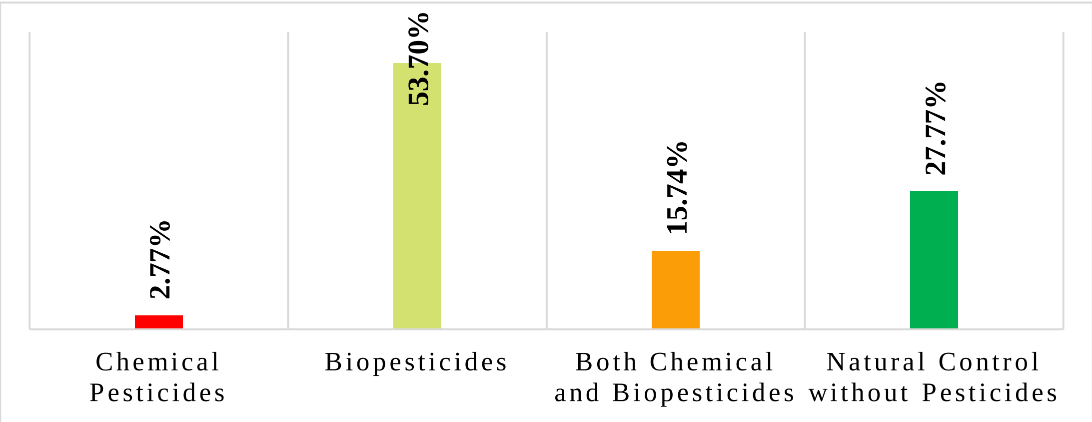
Table 7.1
Intensity of Pest Attack on Organic and Nonorganic Farms

Sl No	Nature of Farming	Intensity of Pest Infestation			Test
		No Pest Infestation	Pest Infestation	Total	
1	Nonorganic	24 (66.7)	12 (33.3)	36	Pearson $\chi2(1) = 4.559$ $p = 0.033$
2	Organic	107 (82.9)	22 (17.1)	129	
Total		131 (79.4)	34 (20.6)	165	

Source: Primary Data

Figure 7.3

Method of Controlling Pests



Source: Primary Data

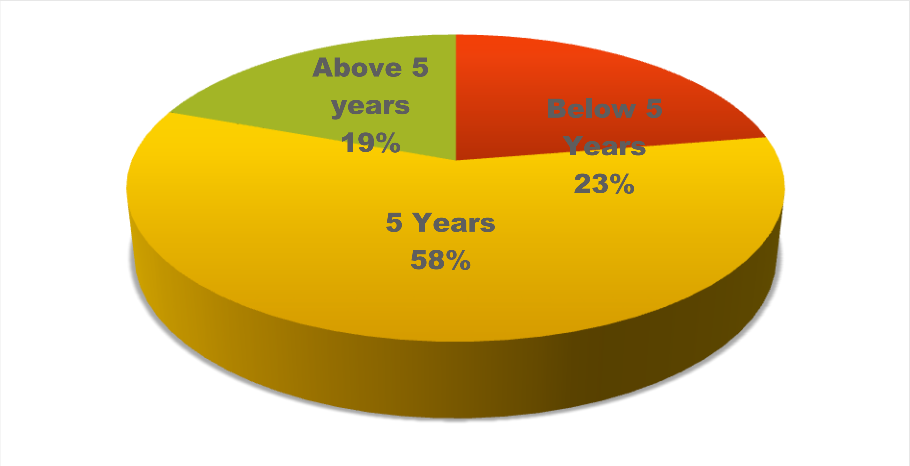
As per figure 7.3, in the state, there were four key pest management measures for greenhouse farming. Chemical pesticides, biopesticides, a combination of chemicals and biopesticides, and natural pest control without pesticides were all used. It is encouraging that more than half (53%) of the greenhouses used only bio-pesticides, and another 27.7 percent did not use any organic or non-organic pesticides. About 18 percent of all greenhouses used chemical pesticides. Only 2.7 percent of these were treated solely with chemical pesticides.

7.2.2 Short Durability of Roofing and Side Covering Sheets

Polyethene sheets were used to cover the roofs and sides of all greenhouses in the state. Due to the state's unique climatic circumstances, it lasts only a few years. After that, it becomes a non-biodegradable waste that causes a slew of issues for farmers. Therefore, it was important to examine the durability of the roof and covering materials of the greenhouses in the state. Figure 7.4 shows that 23 percent of greenhouses used the covering materials for less than five years, 58 percent of farms used them for five years, and only 19 percent of greenhouses used them for more than five years. In other words, 81 percent of greenhouses had changed their roofing and covering sheets by the end of five years.

Figure 7.4

Durability of Roofing and Side Covering Sheets



Source: Primary Data

The durability of covering and roofing materials for greenhouses of various sizes is shown in Table 7.2. Accordingly, the average lifespan of all greenhouses was 5.1 years. Very large greenhouses had the best average durability (5.62 years), followed by large greenhouses, while small greenhouses had the worst (4.63 years). Large greenhouses have a maximum lifespan of ten years, whereas smaller greenhouses have a minimum lifespan of five years. Prolonged rain in the state for over six months caused moss to grow on the covering and roofing sheets, which made them last less.

Table 7.2

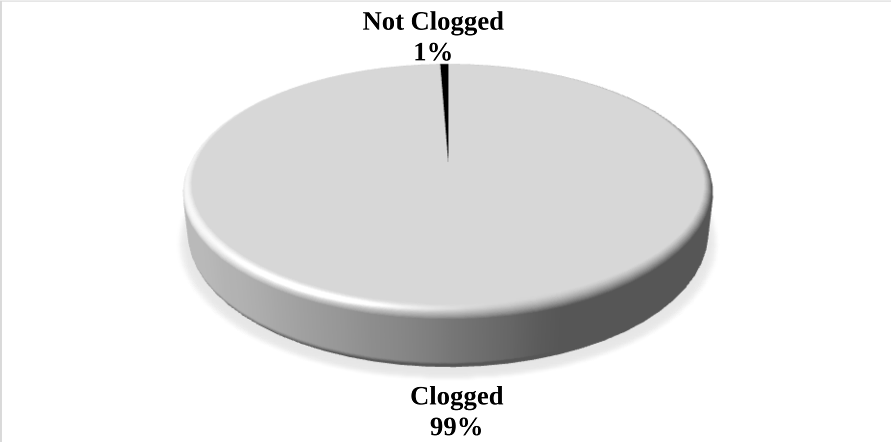
Durability of Roofing Sheet of Various Sizes of Greenhouses

SL No	Size of GH	Average Durability in Years	Minimum Durability in Years	Maximum Durability in Years
1	Very Small (Up to100 sq. m)	5.15	4	6
2	Small (101 - 300 sq. m)	4.63	4	6
3	Medium (301-500 sq. m)	4.99	2	9
4	Large (501-1000 sq. m)	5.26	3	10
5	Very Large (Above 1000 sq. m)	5.62	4	8
All		5.1	2	10

Source: Primary Data

Moss blockage on the roof and side covering sheets has damaged approximately 99 percent of greenhouses, according to figure 7.5. As a result of the lack of adequate sunlight entering the greenhouses, productivity has been lowered. Furthermore, 22.4 percent of greenhouse operators lacked a suitable strategy for clearing clogged moss and dust from the covers. The traditional and rudimentary approach of washing to clear the obstructed moss was used by the remaining 77.6 percent. Farmers, on the other hand, found this strategy prohibitively expensive to execute. According to table 7.3, 27 percent of medium farmers, 23 percent of large farms, and 21 percent of very small farmers had no answer to the problem. All small greenhouses had a solution to remove the clogged moss from the sheets. However, because the current method of washing is arduous and expensive, technology must be developed to remove clogged moss from the roof and side coverings.

Figure 7.5
Moss Clogging on Roof and Side Covering



Source: Primary Data

Table 7.3

Remedial Measure to Remove Moss of Various Sizes of Greenhouses

SL No	Size of GH	Had no solution to remove moss and dust	Had a solution to remove moss and dust
1	Very Small (Up to100 sq. m)	4 (21.1)	15 (78.9)
2	Small (101 - 300 sq. m)	0	11 (100)
3	Medium (301-500 sq. m)	24 (27)	65 (73)
4	Large (501-1000 sq. m)	7 (23.3)	23 (76.7)
5	Very Large (Above 1000 sq. m)	2 (12.5)	14 (87.5)
All		37 (22.4)	128 (77.6)

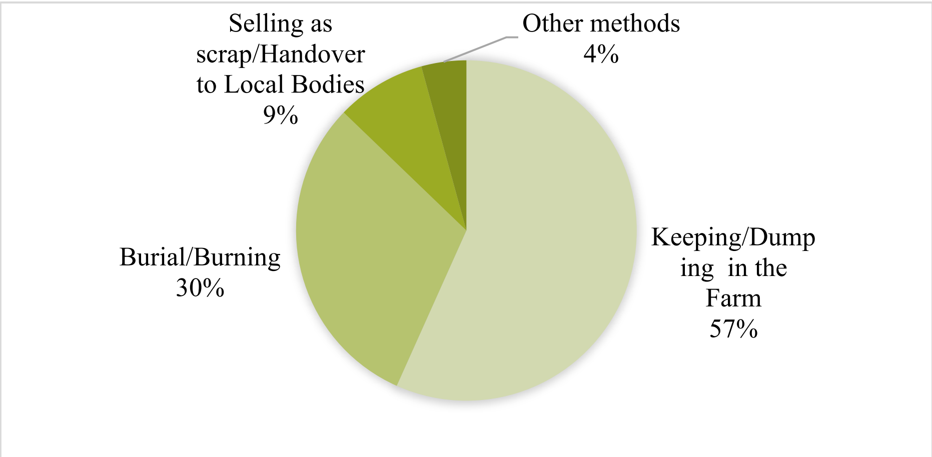
Source: Primary Data; Values in parenthesis are percentages of row total

7.2.3 Strategy for the Disposal of Used Roofing and Covering Sheets

Plastic sheets are commonly used in Kerala to construct greenhouse roofs and side coverings. Because the average usable period was only five years, it was difficult for the farmers to dispose of them without causing significant environmental damage. As a result, it is critical to investigate how greenhouse vegetable farmers in Kerala dispose of their waste. The various techniques utilised by farmers to dispose of plastic material used for roofing and side covers are depicted in Figure 7.6. Unfortunately, 57 percent of the farms lacked an effective disposal strategy. They either kept them or discarded them in the greenhouses' corners or open pastures. Another 30 percent of farmers buried or burned them on the field, which is an unscientific practice. This method is hazardous to one's health as well as the environment. Nine percent of farmers, on the other hand, took part in the scientific disposal by handing them over to scrap vendors or local body authorities. Another 4 percent of farmers attempted to reuse them by mulching open fields to prevent weeds and retain moisture in the soil. In short, 87 percent of farmers had no proper strategy to dispose of the removed roofing and side covering sheets of greenhouses.

Figure 7.6

Disposal Strategy of Used Roofing and Covering Sheets



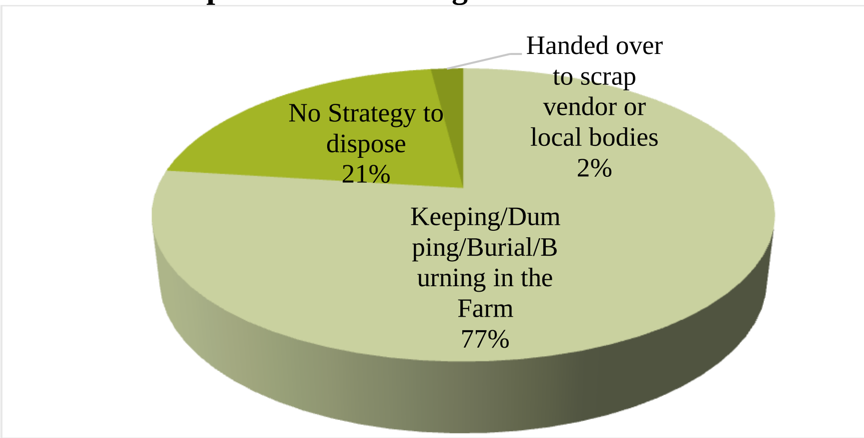
Source: Primary Data

7.2.4 Disposal of Used, Nonbiodegradable Waste Materials

Greenhouses produce nondegradable items such as plastic tags, ribbons, bags, and threads in addition to the roofing and covering materials used. A proper strategy for the scientific disposal of them is required to minimise harm to human health and the environment. The approach used by greenhouse growers in Kerala to dispose of non-degradable items is seen in Figure 7.7. Accordingly, 98 percent of greenhouse farmers had no scientific method in place to dispose of these waste materials. 77 percent of the farmers dumped, burned, or buried them on the farm, which is an unscientific practice. Only 21 percent of farmers have a method in place to get rid of them. Only two percent of the farmers used the scientific method of delivering scrap to scrap vendors or local authorities for recycling.

Figure 7.7

Disposal of Nonbiodegradable Waste Materials

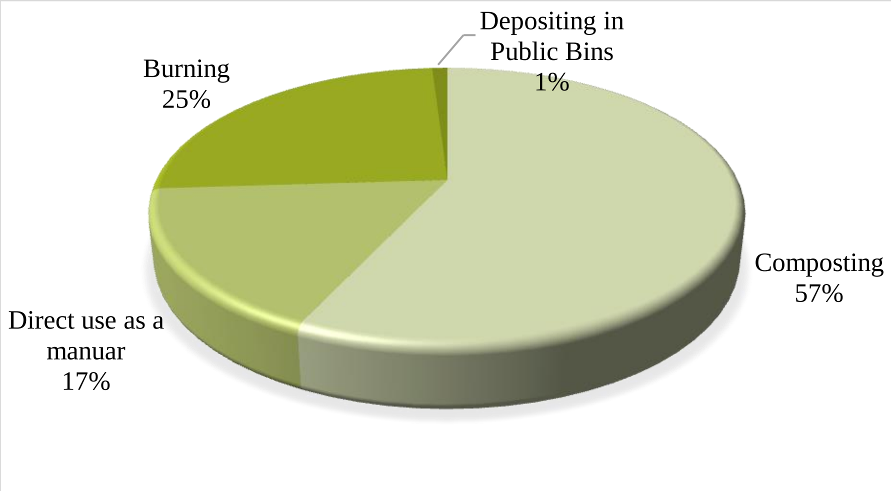


Source: Primary Data

7.2.5 Disposal of Degradable Waste Materials

In greenhouses, there is a huge volume of decomposing garbage in addition to non-degradable trash. Crop residues make up the majority of it. Greenhouses can dispose of such trash in a variety of ways. These include scientific composting processes and direct application as manure, as well as non-scientific methods such as just dumping them in a public garbage container or burning them in the corner of the field. Figure 7.8 shows which of these strategies were most commonly used by greenhouse farmers in Kerala. Accordingly, 74 percent of the farmers used a scientific approach to disposal. 57 percent of the farmers composted the material in a compost pit, while 17 percent used it directly as manure. However, 26 percent of farmers used this unscientific practice. Twenty-five percent of the farmers burned the garbage after it had dried out. Only one percent of farmers used public dumpsters to dispose of their waste.

Figure 7.8
Disposal Strategy of Degradable Waste Materials



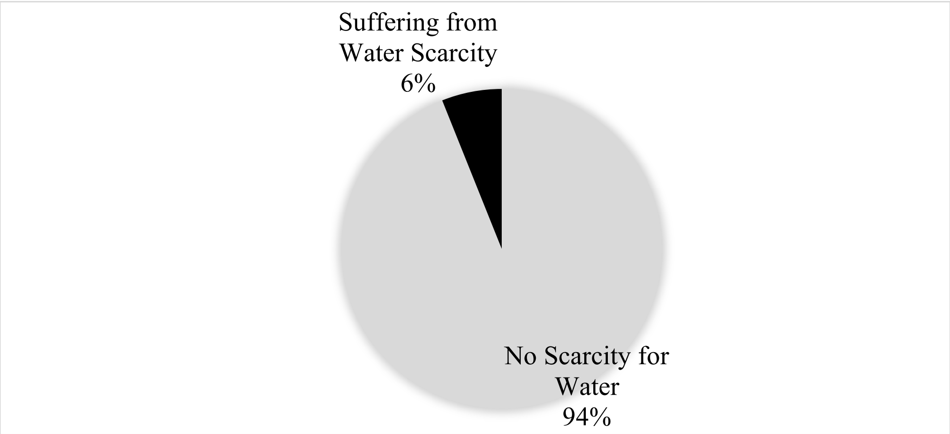
Source: Primary Data

7.2.6 Scarcity of Water for Irrigation

Greenhouses utilise less water than open fields since they employ drip irrigation. However, it is possible to determine how many greenhouses have adequate water for cultivation and how many are experiencing water shortages. Figure 7.9 shows that 94 percent of greenhouses had enough water to irrigate, whereas just six percent experienced a water shortage.

Figure 7.9

Availability of Water for Irrigation



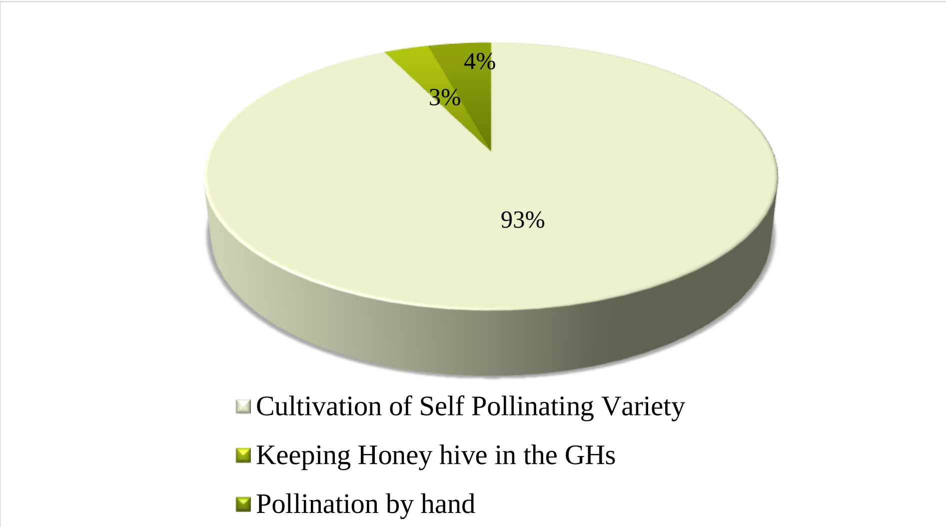
Source: Primary Data

7.2.7 Pollination of Crops

Except for leafy vegetables like spinach, cabbage, and cauliflower, pollination is required for vegetable crop production. In greenhouses, various pollination methods are utilised. There are mechanical methods like vibrators and fans, as well as biological methods like beehive installation and manual pollination, as well as the production of self-pollinating cultivars. Figure 7.10 depicts the various methods used by Kerala greenhouse farmers to pollinate their crops. As a result, 93 percent of farmers chose self-pollinating kinds or crops that don't need pollination. Three percent of the remaining seven percent of farms used honey hives in the greenhouse for crop pollination, while four percent of farmers pollinated by hand. To avoid the pollination constraint, nearly all farmers cultivated self-pollinating crop varieties. As a result, only a small number of crops, such as yardlong beans, salad cucumbers, and spinach, were mostly grown in greenhouses in Kerala.

Figure 7.10

Pollination Strategy of GHs



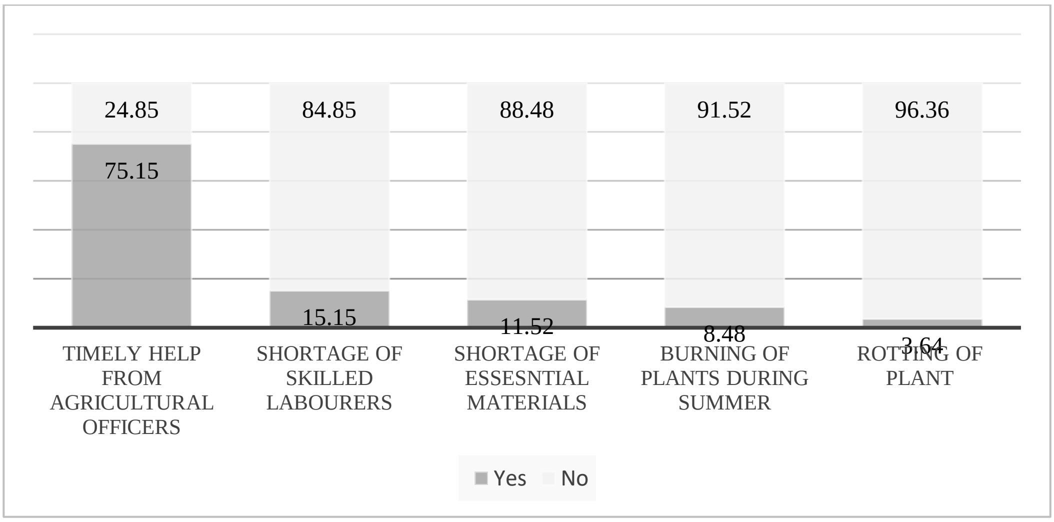
Source: Primary Data

7.2.8 Other Major Technical Constraints of GH Vegetable Farming

There were also further obstacles to greenhouse vegetable cultivation in Kerala, in addition to the ones described above. Among them were a lack of timely guidance and support from agricultural officers, a paucity of competent labour and critical resources, plant burning during the summer, and plant rotting during the rainy season. The proportion of greenhouses affected by these limits is depicted in the graph below.

Figure 7.11

Proportion of GHs with Various Constraints



Source: Primary Data

Figure 7.11 shows that 24.85 percent of greenhouses did not obtain timely assistance from agriculture officers, whereas 75.15 percent did. The scarcity of skilled labour to do farm tasks was not severe. Only 15.15 percent of farmers were affected by the scarcity of skilled labour, while 84.85 percent were not. When compared to skilled labour, the intensity of the lack of essential materials was lower. 11.52 percent of farmers reported a lack of necessary resources for greenhouse vegetable cultivation. During the scorching summer, 8.48 percent of farmers experienced plant burnout. Plant rotting, on the other hand, was extremely low (only 3.64 percent) during the rainy season.

7.3 Economic Constraints of High-tech Farming

High-tech cultivation in greenhouses is subject to various economic constraints in addition to technical ones. These constraints will be classified as market constraints, debt-related constraints, subsidy disbursement constraints, and risk-related constraints. The following sections deal with all these in detail.

7.3.1 Market Constraints

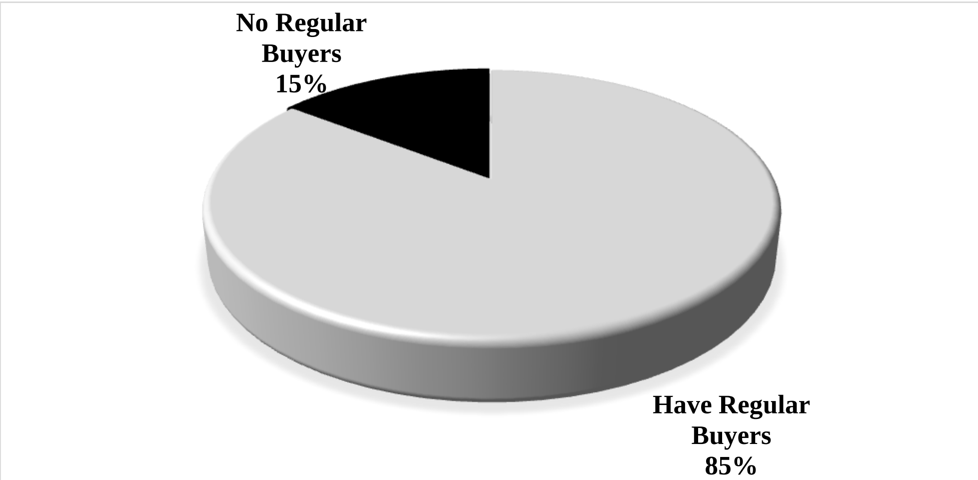
Proper marketing is vital for the economic success of any economic activity, including high-tech vegetable cultivation in greenhouses. The market constraints are the lack of regular buyers for the product, insufficient prices, irregularities in the payment by buyers of the product, and so on.

7.3.2 Irregularity of Buyers for Greenhouse Vegetable Products

Harvesting must be done every day in greenhouse vegetable growing. As a result, there should be enough buyers to purchase the products, as they are perishable within one or two days. Figure 7.12 depicts the availability of regular buyers for greenhouse-grown vegetables. Accordingly, 15 percent of vegetable growers were unable to sell their produce due to a lack of suitable purchasers. However, the majority of the farmers (85%) had enough buyers to sell their products.

Figure 7.12

Regular Buyers for GH Products

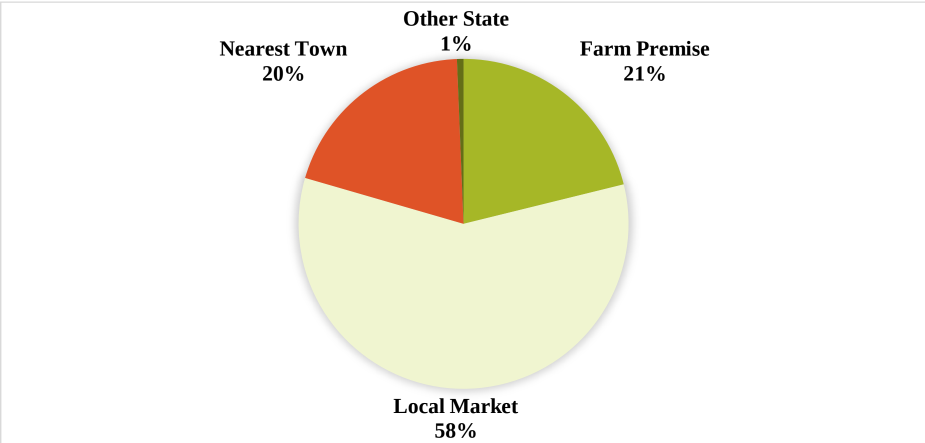


Source: Primary Data

Furthermore, figure 7.13 shows the distribution of regular buyers in the market. The majority (58%) of the farmers had regular buyers in the local market. The other sources of buyers were from the farm premises (21%), followed by the nearest town (20%). Only a very few farmers (1%) found buyers from other states. To put it another way, 99 percent of farmers found markets for their products on the farm, in local markets, or in towns nearby.

Figure 7.13

Distribution of Regular Buyers

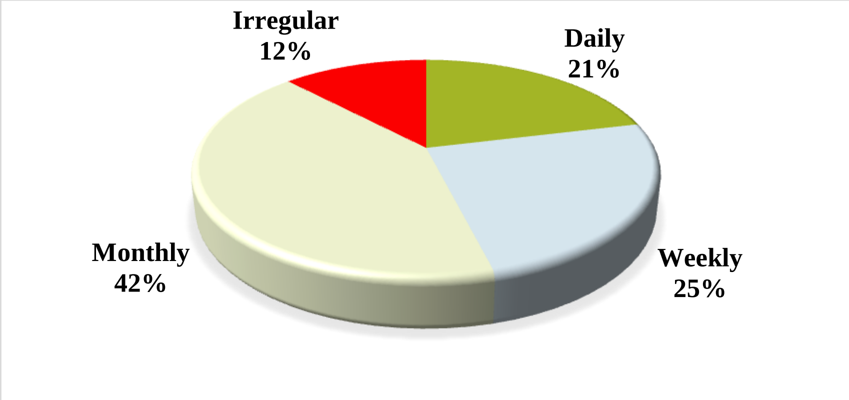


Source: Primary Data

Another barrier for greenhouse growers is the time it takes to receive revenue from the market. The frequency of obtaining revenue from the market is depicted in figure 7.14. Accordingly, 12 percent of farmers received the revenue irregularly, while 42 percent of farmers' receiving time was one month. Only 21 percent of greenhouse farmers earned sales revenue every day, and another 25 percent received it every week. In other words, 54 percent of farmers received their payments irregularly or over a month's time.

Figure 7.14

Frequency of Revenue Received from the Market

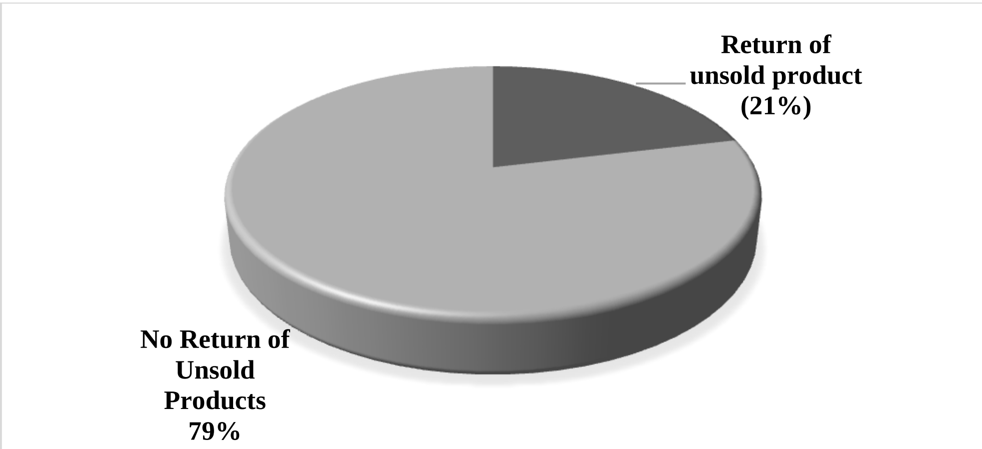


Source: Primary Data

The problem of unsold products being returned to the market is depicted in Figure 7.15. Because vegetables are perishable commodities, returned products will quickly deteriorate, resulting in a significant loss. In Kerala, 21 percent of farmers were having trouble returning unsold products to the market. Figure 7.16 also looks at the main reasons for unsold products being returned to the market. According to the figure, farmers' demand for higher prices was the primary cause of the return (60%). Farmers were forced to demand higher prices because the cost of farming was so high in greenhouse vegetable cultivation.

Figure 7.15

Return of Unsold Product from the Market

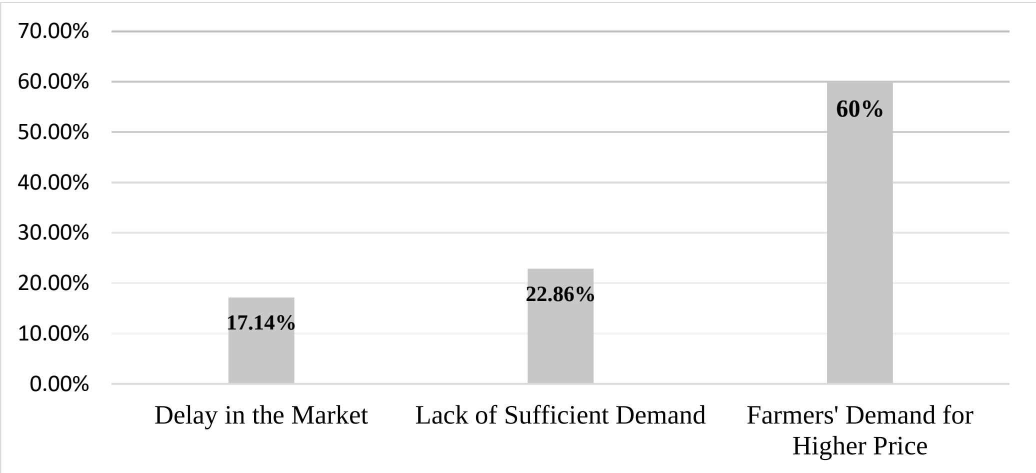


Source: Primary Data

The second key factor was the lack of demand for vegetables in general (21.86%). During the summer, the Kerala market has a plentiful supply of vegetables. Summer is also a good time for greenhouse farmers to increase their output because it is the best season. Consequently, during the summer, the market is overflowing with vegetables. Therefore, there was not enough demand for the farmers' products. The third reason for the product's return from the market was a failure on the part of farmers to deliver their vegetable yield on time. The main cause of the delay was a delay in harvesting and challenges with transportation facilities. However, competition from low-cost open-field crops was the primary cause of the return of 82.86 percent of farmers' products.

Figure 7.16

Major Reasons for Return of Products from Market

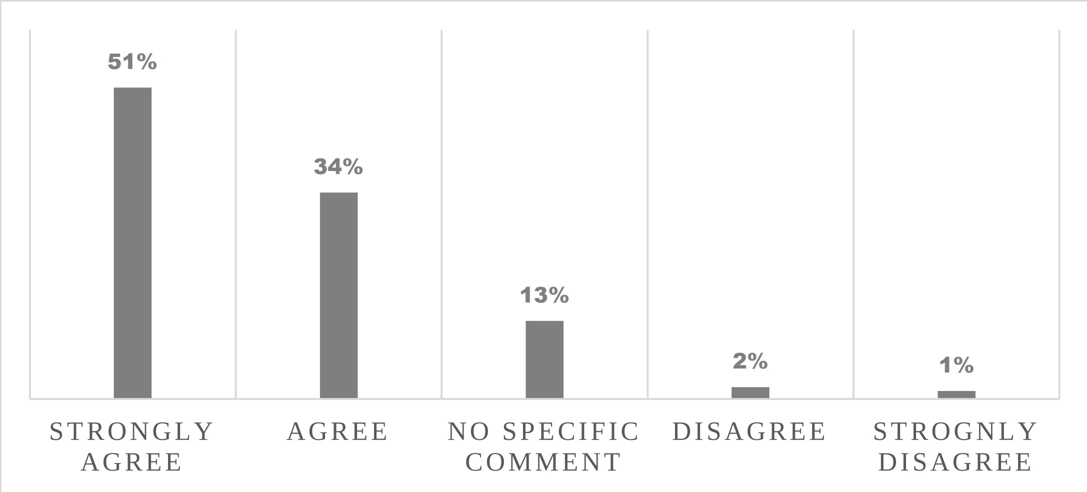


Source: Primary Data

Farmers' views on purchasers' demand for cheap, contaminated vegetables are depicted in figure 7.16. Farmers' observations of buyers' intentions led to the formation of this belief. According to 85 percent of farmers, consumers prefer cheap vegetables grown in open fields, even if they are contaminated with chemical pesticides. Only three percent of farmers held a different viewpoint, while 13 percent had no opinion at all.

Figure 7.17

Buyers' Preference for Cheap Polluted Vegetables: Farmers Opinion



Source: Primary Data

The average score of 4.3 demonstrates that farmers in general concur that consumers prefer inexpensive goods from open-field farms, even if they contain pesticide residue.

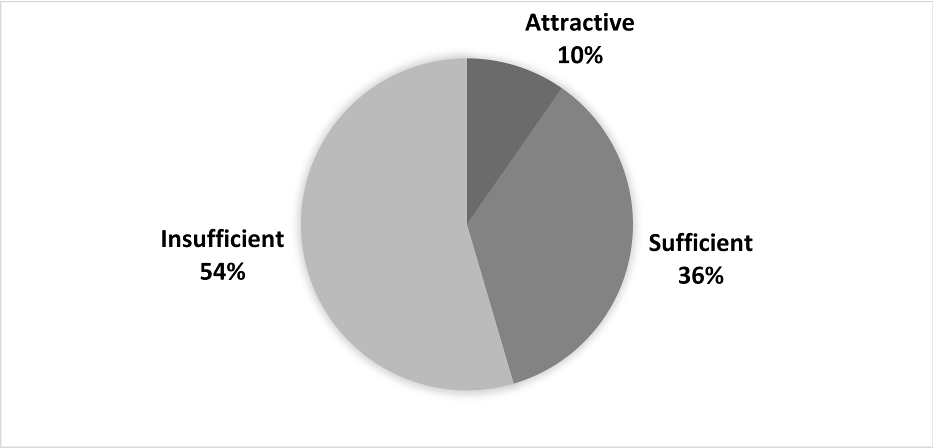
According to George Akerlof's (1970) theory of asymmetric information, vendors have access to more product knowledge than purchasers, which causes a glut of poor-quality products (or "lemons") on the market. Due to the possibility of purchasing a product of poor quality, consumers are reluctant to pay higher prices. Applying this concept to an open-field product-GH product situation, high-quality products (the "GH products") have a hard time competing if low-quality products take the lead because of buyer confusion. Buyers become more cautious as a result of the unclear information, which hurts better choices like GH products.

7.3.3 Insufficient Price of Outputs

An adequate price for the product is critical for a commercial venture's long-term viability. When comparing the cost per kilogramme of output, greenhouse farmers' earnings for vegetable output were insufficient. Only 10 percent of farmers obtained an attractive price for their output, as seen in figure 7.18, while 36 percent received a sufficient price. Unfortunately, the majority of farmers (54%) were paid insufficiently for their produce. As shown in figure 7.19, all vegetable crops produced by greenhouse farmers in Kerala obtained lower prices than the required pricing to support the agricultural operation. Crops including tomatoes, capsicum, cabbage, and cauliflower are sold at 50 percent less than the needed price. Major crops, including the yardlong bean, salad cucumber, and bitter gourd, had prices that were 20 percent, 24 percent, and 36 percent lower than what was required, respectively. Green Chilli was the only crop that came close to receiving the required price.

Figure 7.18

Prices Received for GH Crops



Source: Primary Data

Figure 7.19

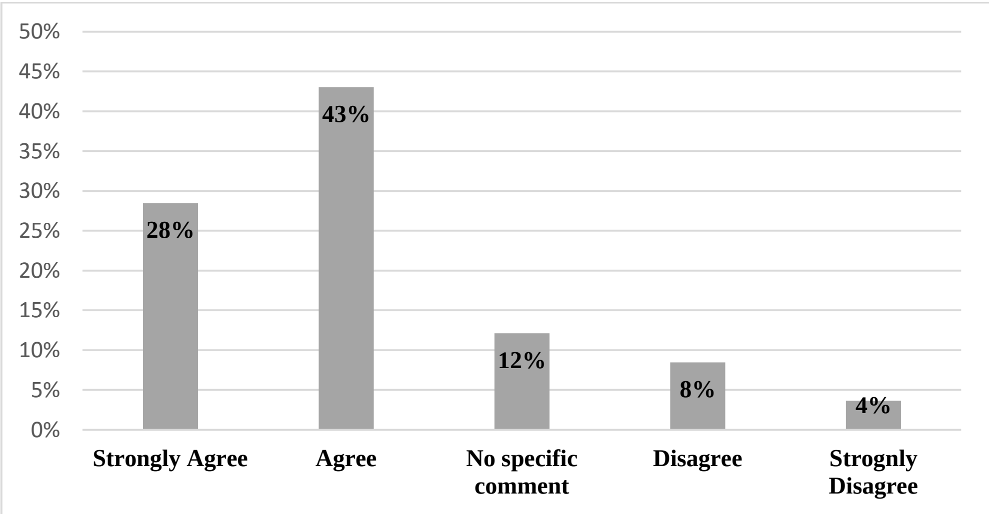
Average Price Required and Received for Various Crops

Source: Primary Data

The behaviour of vegetable merchants was one of the key factors in the decreased prices for greenhouse vegetable crops. Figure 7.20 shows that 71 percent of greenhouse farmers believed merchants had attempted to lower the prices of products supplied by farmers. Only 12 percent of the farmers disagreed with this, while another 12 percent had no specific opinion.

Figure 7.20

Farmers' Opinion on Merchants' Behaviour of Reducing Prices



Source: Primary Data

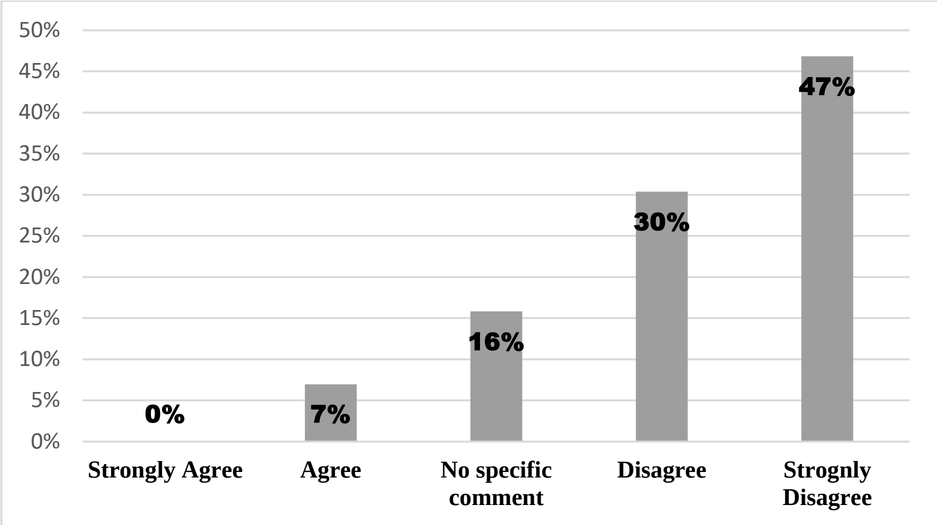
As the average score is 3.87, farmers agree altogether with the statement that merchants always try to reduce the price of products supplied by greenhouse vegetable farmers.

7.3.4 Official Help to Market the Product: Farmers' Opinion

As the farmers were not organised, support from government agencies or farmers' associations would have a key role in providing market opportunities. However, the majority of farmers did not receive such support.

Figure 6.21

Farmers' Opinion on Help from Official Agencies to Market the GH Products



Source: Primary Data

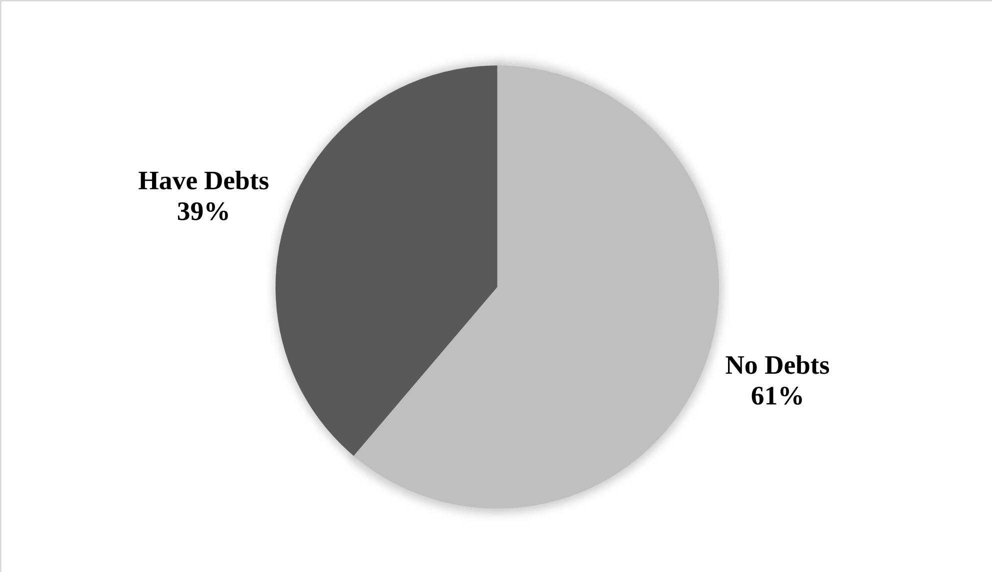
Figure 7.21 shows that 77 percent of the farmers opined that they did not receive any support, while only seven percent agreed. Another 16 percent of farmers did not have an opinion regarding this. As the average score is 1.8, farmers altogether strongly disagree with the statement regarding the support received from farmers' associations or government agencies to market their output.

7.3.5 Debt Burden of Greenhouse Farmers

The debt burden is usually a significant barrier for farmers. Greenhouse farmers are also not debt-free, as the majority of them have taken out loans from a variety of sources to cover the high cost of building greenhouses and installing various greenhouse amenities. As shown in Figure 7.22, 39 percent of greenhouse farmers have taken out loans from a variety of sources. The main sources of loans were scheduled banks, cooperative banks, local money lenders, and friends and family. The proportion of loans taken from various sources by greenhouse farmers is depicted in Figure 7.23. Accordingly, 56 percent of farmers owed money to scheduled banks, while 39 percent owed it to cooperative banks. The remaining three percent borrowed money from friends and relatives, while two percent borrowed from local money lenders. Nobody has ever borrowed money from a non-banking financial institution. Despite this, the fact that 95 percent of the debts were held by organised-sector financial institutions is reassuring.

Figure 7.22

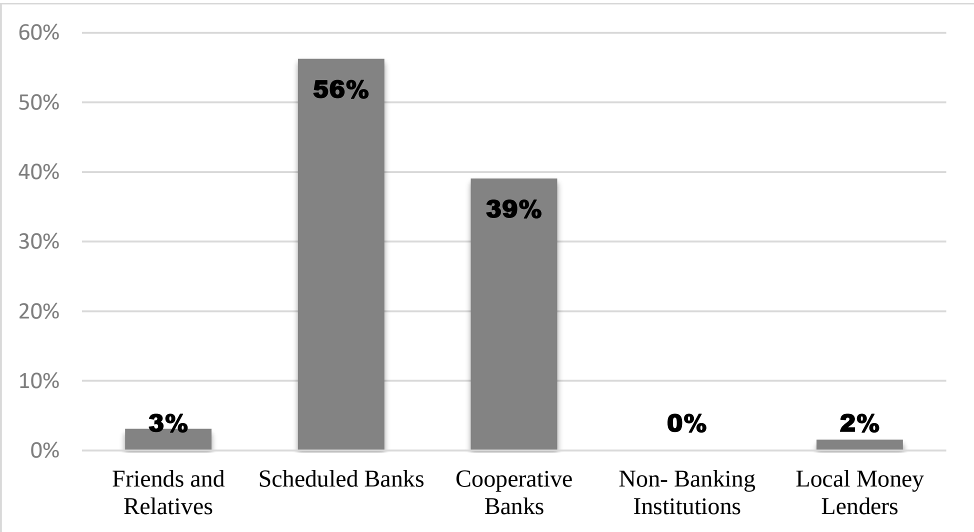
Intensity of Debt Burden among GH Farmers



Source: Primary Data

Figure 7.23

Loan Sources of GH Farmers



Source: Primary Data

7.3.6 The Debt Burden among Different Sizes of Farms

The financial burden, however, differed depending on the size of the greenhouse. The condition is depicted in table 7.4.

Table 7.4

Debt Burden among Different Sizes of GHs

Farm Size		No Loan	Have Loan	Total	Test
Very Small (Up to100 sq. m)	Count	19	0	19	Pearson χ^2 Value 23.73 Df: 4 Prob: 0.000
	%	100.0%	0.0%	100.0%	
Small (101 - 300 sq. m)	Count	9	2	11	
	%	81.8%	18.2%	100.0%	
Medium (301-500 sq. m)	Count	53	36	89	
	%	59.6%	40.4%	100.0%	
Large (501-1000 sq. m)	Count	16	14	30	
	%	53.3%	46.7%	100.0%	
Very Large (Above 1000 sq. m)	Count	4	12	16	
	%	25.0%	75.0%	100.0%	
Total	Count	101	64	165	
	%	61.2%	38.8%	100.0%	

Source: Primary Data

a. 1 cells (10.0%) have expected count less than 5. The minimum expected count is 4.27.

Table 7.4 presents data regarding farm sizes and their association with loan availability. The farms are categorised based on their size ranges, starting from "very small" (up to 100 sq. m.) to "very large" (above 1000 sq. m.). The "Count" column displays the number of farms falling into each category. The subsequent columns show the distribution of farms with respect to loan status: "No Loan" and "Have Loan". The percentage distribution of farms in each category is also provided.

From the data, it is apparent that farms in the "very small" category exclusively have no loans, indicating a lack of access to credit within this size range. As farm sizes increase, the percentage of farms with loans gradually rises, with the "very large" category having the highest proportion of farms with loans (75.0%). The Pearson $\chi2$

test was conducted to assess the relationship between farm size and loan availability, yielding a significant test statistic (23.73) with a p value of 0.000, suggesting a notable association between the variables. This table highlights the trends in loan access across different farm sizes, underscoring the relationship between farm sizes and loan availability.

Table 7.5

The Intensity of Debt Burden among Different Sizes of Farms

Sl No	Size Category	Number of Farms	Average Debt per farm (Rs)	Average Debt per sq. m (Rs)
1	Very Small (U pto100 sq. m)	19	00	00
2	Small (101 - 300 sq. m)	11	31318.18	158.40
3	Medium (301-500 sq. m)	89	148078.65	360.81
4	Large (501-1000 sq. m)	30	333333.33	395.49
5	Very Large (Above 1000 sq. m)	16	1061250.00	565.21
Total		165	245509.00	331.89

Source: Primary Data

Table 7.5 shows how the debt burden varies depending on the size of the greenhouse. As previously indicated, no farm in the category of very small farms has any debt. The average debt per greenhouse increased from Rs. 31318 to Rs. 1061250 for small to large farms. The average debt per sq. m. area, as shown in the last column of table 7.5, is a more useful tool for determining the severity of the debt burden. The total debt per sq. m. for all farms was Rs. 332. Very large farms had the highest debt burden (Rs. 565.21), followed by large (Rs. 395), medium (Rs. 361), and small farms (Rs. 158). To put it another way, the debt burden of very large farms was 258 percent greater than that of small farms. It was due to very large farmers' reliance on borrowed funding for investment.

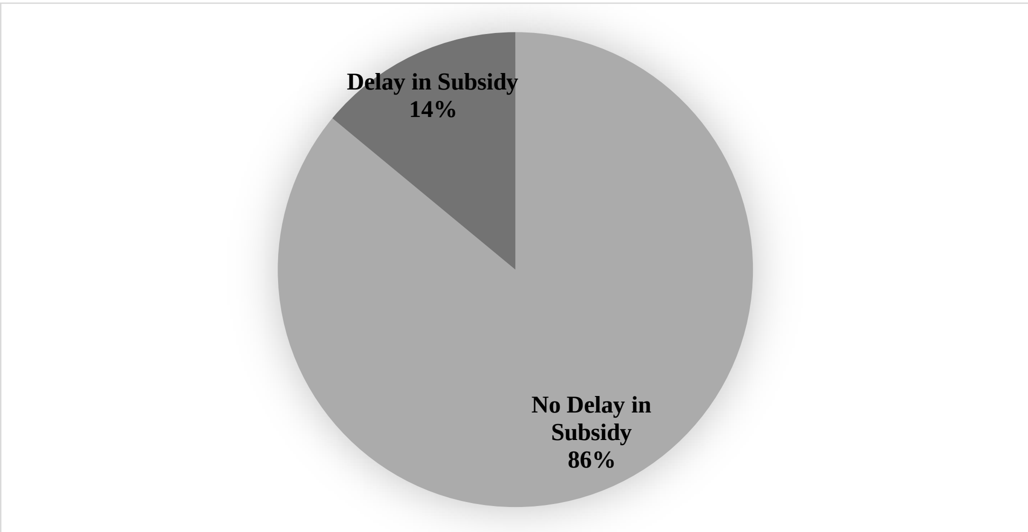
Other socioeconomic factors, like whether a high-tech farmer worked full-time or part-time, whether they lived in a rural or urban area, how much education they had, or what religion they belonged to, did not make a big difference in how much debt they had.

7.3.7 Problems in Disbursement of Subsidy

As seen in the fourth chapter, the government's subsidy for greenhouse construction was crucial for the viability of greenhouse vegetable farming. The average subsidy availed per sq. m. area by very small greenhouses was the highest (Rs. 1047.88), followed by medium (Rs. 718.95) and large (Rs. 718.7). The least amount of subsidy was availed by small greenhouses (Rs. 562.35), followed by very large greenhouses (Rs. 702.35). Even though everyone got the subsidy, many farms had trouble getting it on time or did not get enough of it.

Figure 7.24

Delay in the Distribution of Subsidy

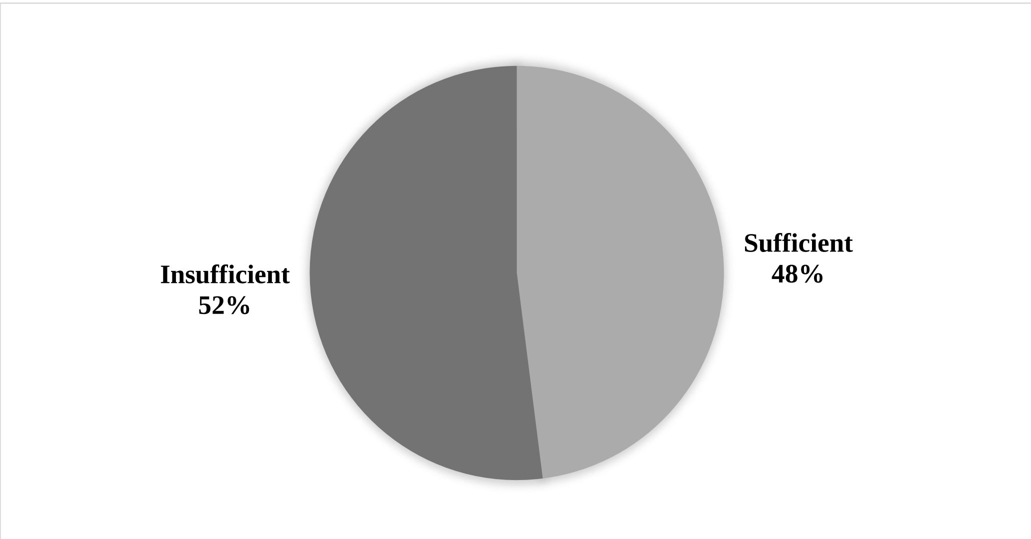


Source: Primary Data

As figure 7.24 shows, 14 percent of greenhouses experienced delays in the receipt of subsidies, while 86 percent experienced no delays. Furthermore, as figure 7.25 depicts, a major share (52 % of farmers) opined that the existing rate of subsidy was not sufficient to meet the very high cost of greenhouse construction and the implementation of essential facilities in them. The insufficiency of subsidies hindered the farmers' installation of modern equipment in greenhouses. This is the major reason for the semi-high-tech nature of greenhouses in Kerala, which prevented the utilisation of the full potential of high-tech technology in vegetable cultivation.

Figure 7.25

Sufficiency of Subsidy



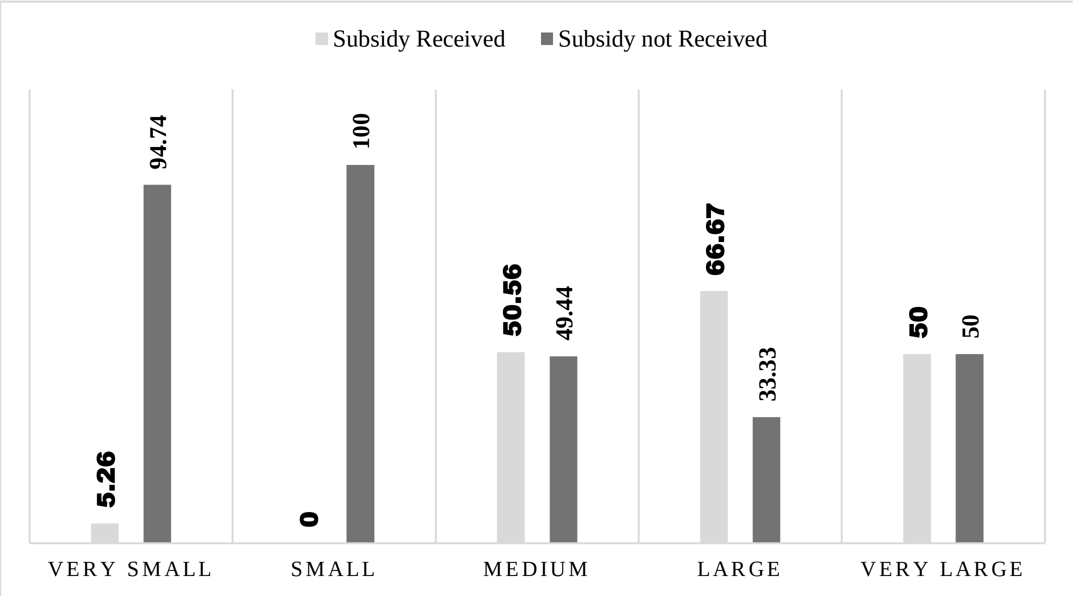
Source: Primary Data

7.3.8 Subsidy to Meet Recurring Expenditures

Aside from subsidies for greenhouse construction, the government also provides subsidies to cover recurring expenses. This form of financial assistance is necessary to keep farmers in the high-tech way of greenhouse production. Table 7.6 and figure 7.26 show in detail how subsidies were given out to help farmers pay for recurring costs.

Figure 7.26

Proportion of GHs Received Subsidy to Meet Recurring Expenditures



Source: Primary Data

Table 7.6

Distribution of Subsidy to Meet Recurring Expenditures

Sl No	Size Category	Number of Farms	Average Subsidy Received per sq. m (Rs)	Total Subsidy Received (Rs)
1	Very Small (U pto100 sq. m)	1	100	3000
2	Small (101 - 300 sq. m)	0	0	0
3	Medium (301-500 sq. m)	45	119.63	2206000
4	Large (501-1000 sq. m)	20	158	2538000
5	Very Large (Above 1000 sq. m)	8	173	2253000
Total		74	135.5	7000000

Source: Primary Data

Accordingly, despite the fact that 74 farmers (44.84 percent) received subsidies for this purpose, there was a disparity in proportion and average amount among greenhouses of various sizes. 66.6 percent of large farms, 50.56 percent of medium farms, and 50 percent of very large farms were successful in obtaining a subsidy to cover recurring costs. Small farms, on the other hand, did not receive any subsidies, and only one very small farm (5.26 percent) obtained a subsidy for this purpose. There was a direct correlation between greenhouse size and the amount of average subsidy for meeting recurring expenses. Very large farms received the greatest average subsidy per sq. m. area (Rs. 173), followed by large greenhouses (Rs. 153) and medium greenhouses (Rs. 119.63).

The lower proportion and average amount of recurrent subsidies to small and very small greenhouses were due to their decreased reliance on purchased products. Medium, large, and very large farms were eligible for the greater subsidy due to their reliance on hired labour and purchased materials.

7.3.9 Lack of Insurance for Greenhouses and Crops

It is critical to have insurance coverage for greenhouses and the crops grown in them in order to be protected from extreme weather. Kerala is one of the Indian states that is vulnerable to natural disasters, including floods, landslides, and storms. Crop failure and, as a result, financial loss for farmers is common as a result of extreme weather. Greenhouse farmers lose a lot of money because of the damage to their greenhouses and the crops they grow in them. Many greenhouses and the crops inside them were destroyed during the Ockhi cyclone in 2017, which hit areas like Thiruvananthapuram, Kollam, and Alappuzha. As a result of the severe damage caused by this natural disaster, a lot of farmers abandoned greenhouse farming. The primary cause was farmers' failure to insure greenhouses and crops. The following graphs show the lack of insurance among Kerala greenhouse vegetable farmers.

Figure 7.27.1 Insurance to GHs

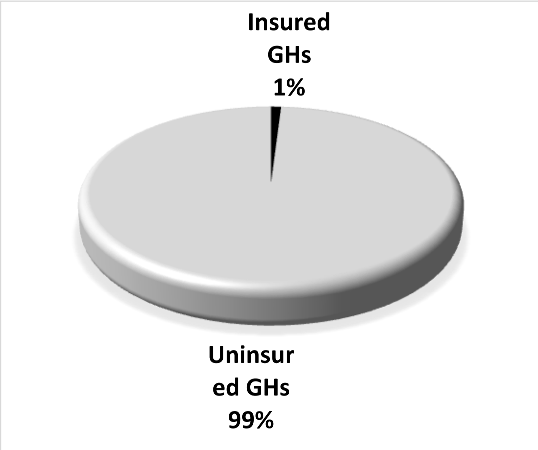
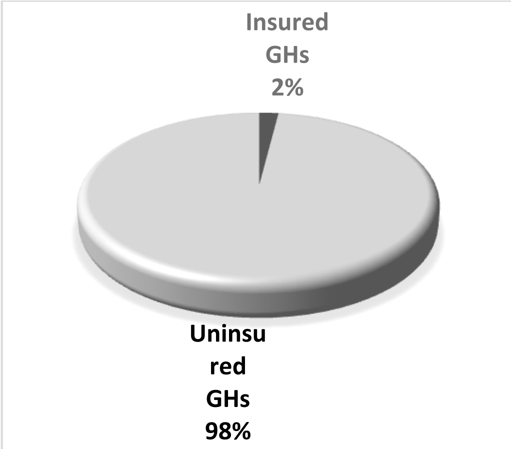


Figure 7.27.2 Insurance to GH Crops



Source: Primary Data

Only one percent of farmers insured their greenhouses against natural calamities and fire outbreaks, according to figure 7.27.1. It reveals a flaw in the technique of insuring greenhouses, which are expensive to construct. On the other hand, figure 7.27.2 illustrates the extent of the practice of insuring the crops grown inside the greenhouses. Similar to the insurance of greenhouses, crop insurance among greenhouse vegetable farms was very rare. Only 2 percent of farmers insured their crops grown in greenhouses. The lack of awareness and the deficiency of suitable insurance policies were the major reasons for the reluctance of farmers to insure the crops as well as the greenhouses.

7.4 Conclusion

Greenhouse vegetable growers in Kerala had numerous challenges to face. These challenges were classified as technical and economic constraints. Pest infestation, moss and dust clogging on the roof, disposal of used covering sheets and other materials such as tags, threads, and plastic bags, disposal of biodegradable material wastes, lack of proper pollination of crops, lack of timely support from government offices, and a shortage of skilled labour and essential materials were the major technical constraints faced by greenhouse vegetable farmers. The economic constraints include market-related constraints, debt burden, insufficiency of subsidies, and a lack of insurance for greenhouses and crops. Buyer irregularities, delays in receiving money for products sold, returns of unsold vegetables, insufficient product pricing, and merchants' deliberate move to undercut the price of vegetables supplied by farmers were the key market-related limitations. Regarding the debt burden, 38.8 percent of the farmers had debt outstanding. Even though there were variations among different sizes, the average debt per sq. m. area of all greenhouses was Rs. 331.89. Despite the fact that all greenhouses were provided with a subsidy, farmers believed that the amount was insufficient to cover the high building costs. Furthermore, only 44.8 percent of farmers received subsidies to cover recurring farming expenses. Farmers were exceedingly hesitant to insure greenhouses and the crops they contained. There were only one percent of total greenhouses and two percent of greenhouse crops that had insurance.

CHAPTER VIII
FINDINGS, RECOMMENDATIONS AND CONCLUSION

8.1 Introduction

Food production in general, and vegetable production in particular, in Kerala is insufficient to meet the state's needs. The state imports the vast majority of its vegetables and fruits from neighbouring states. This insufficiency can also be noticed in vegetable consumption. In Kerala, the average daily intake of fruits and vegetables is lower than the recommended amount. It leads to a slew of health issues. Various investigations have discovered that traces of pesticide residue could be found in a significant portion of the vegetables sold in Kerala. Hi-tech vegetable cultivation was started with high hopes in the special circumstances of Kerala. After a few years of low growth and expansion, the venture was poised to achieve high growth in the number of farms and areas of cultivation. Its technical practicality and necessity have been widely accepted. Agronomists have also worked hard to spread the practice among farmers. They only considered the economic side of it as one of the many factors. Hence, the lack of a comprehensive economic analysis was very visible in this sector. In this context, this study mainly focused on the economic potential and challenges of high-tech vegetable cultivation in greenhouses.

This chapter is divided into three parts. The first section summarised the study's main findings. The second portion contains crucial policy implications and recommendations. Finally, the third component suggests areas for further research. The following are the major findings of this study:

8.2 Major Findings

- The state of Kerala's daily vegetable requirement was around 7500 MT, resulting in a 3200 MT shortfall. As a result, it was discovered that Kerala only generated enough to meet 57 percent of its total demand. Imports from neighbouring states covered the remaining 43 percent of demand.

- All of Kerala's districts had greenhouse vegetable farming. There were a total of 837 farmers cultivating vegetables in a high-tech farming system on an area of 368117.5 sq. m. in 2019–20. The Idukki district (13.38 percent) had the most high-tech farms, followed by Wayanad (12.78 percent) and Ernakulam (11.59 percent). Pathanamthitta (3.23 percent) had the lowest rate, followed by Kasaragod (3.58 percent) and Kollam (3.82 percent) districts. The Wayanad district had the highest area (13.39%), then Thiruvananthapuram (12.95%) and Idukki (11.97%).

- Since the inception of this technology in Thrissur in 2009-10, the venture has grown at a rapid pace until the year 2013-14. With the exception of 2017–18, the sector's growth began to slow in subsequent years. However, such an exception was not visible in the area of high-tech vegetable cultivation in the state. The growth of both the number of farms and the area of farms has declined rapidly and eventually merged into negative growth rates.

- There was a significant difference in the size of farms in various districts. Large farms were prevalent in Kannur, Kollam, and Palakkad districts, while small farms were concentrated in Kasargode, Thrissur, and Kottayam districts.

- The size of the farms built in different years varied significantly. Farms started in 2011–12 were the largest, followed by 2014–15 and 2015–16, while farms started in 2010–11 were the smallest, followed by 2009–10.

- During the last eleven years, a total of Rs. 26.40 crore has been distributed in various districts as greenhouse subsidies. The district of Wayanad received the most money, followed by Thiruvananthapuram, Ernakulam, and Idukki. Despite having the most farms, the Idukki district came in fourth in terms of getting subsidies. Farmers in Kozhikode district received the greatest average subsidy per sq. m. (Rs. 776) while farmers in Thrissur district received the lowest amount (Rs. 600). The lowest average subsidy per sq. m. was granted in 2010–11 (Rs. 121.32), while the highest amount was paid in 2017–18 (Rs. 858.64). Furthermore, the average subsidy paid to greenhouses of all sizes was Rs. 717, with the maximum amount (Rs. 1047) given to very small greenhouses and the lowest amount given to small greenhouses (Rs. 562.35).

- Even though the government generously subsidised this venture, it has no influence over the state's vegetable production. This method was followed in 368117 sq. m. only—around 36 ha. It was a very negligible portion of the total area of vegetable cultivation in the state in 2020–21, which was 1.02 lakh ha (Economic Review 2021, page 68).

- Individual farmers from rural areas dominated greenhouse farming. Middle-aged and old-aged males with an education level of intermediate or graduation dominated greenhouse farmers. The share of the Christian community among greenhouse farmers was more than proportionate, and that of the Muslim community was far less than the proportion of their population in the state. Among different caste categories, the lion’s share was accounted for by the general category, followed by OBCs. No SCs or STs were found among greenhouse farmers.

- Greenhouse farming was a part-time activity for the majority of the farmers. Their major occupation was business, followed by open-field cultivation. The majority of greenhouse farmers were marginal farmers with a land holding of less than one ha. Almost all of them secured training in hi-tech farming, except a few.

- More than half of the total greenhouse farms were medium-sized farms with a size of 301 to 500 sq. m. The vast majority of the greenhouses (78%) practiced organic farming.

- If the number of high-tech facilities put in the greenhouses is taken into account, the state's greenhouse farming is considered a semi-tech activity rather than a high-tech one.

- Farmers' average annual output did not change much based on their age, education, religion, caste, or the amount of land they owned.

- The average yearly output of greenhouses did not differ significantly by location (rural vs. urban), mode of cultivation (organic vs. non-organic), roof style (gable, sawtooth, and Quonset), greenhouse direction, ventilation type (naturally ventilated vs. fan ventilated), or existence (lean-to other building vs. separate existence).

- Full-time farmers' annual output was much higher than part-time farmers' in the category of retired people and businesses. Other categories, on the other hand, did not show a significant difference.

- Farmers who trained for at least a week had an average annual output that was 89% higher than farmers who did not train or who trained for less than a week.

- Greenhouses with full side covers and shade nets had higher average annual yields than greenhouses without these features.

- The output in kg per sq. m. area and output per labour hour were used to determine greenhouse efficiency. Regarding area productivity, greenhouses operated by Muslims were less productive than those of no-religion, Hindu, and Christian farmers. Farmers who had taken at least a week of training were much more productive than those who had not.

- The productivity of small greenhouses was less than that of other size categories. However, the difference was significant only in the comparison of small and medium, and small and large farms. No significant difference was found among other pairs.

- The productivity of fully covered greenhouses was far higher than that of their counterparts. Furthermore, the productivity of greenhouses practicing vertical farming was higher than that of their counterparts.

- The type of roof, its direction, the use of shade nets, the type of ventilation, the presence of greenhouses, and the way the plants were grown did not make a big difference in their productivity.

- Labour productivity (kg of output per labour hour) was highest for very large farms, followed by large and medium farms. The lowest labour productivity was found for small farms, followed by very small farms. However, the productivity difference was not significant for the pairs of very small-small, small-medium, medium-very large, and large-very large farms.

- The labour productivity of full-time high-tech farmers was significantly higher than that of part-time farmers.

- No significant difference was found in labour productivity across gender, education, age, religion, caste, occupation, land holding, and training of greenhouse farmers. Similarly, no significant difference in labour productivity was found across roof type, location, direction, usage of shade net, ventilation, existence, and method of cultivation of greenhouses in Kerala.

- Regarding the number of farms, the yardlong bean was the most prominent crop cultivated in Kerala, followed by salad cucumbers and tomatoes. However, regarding the quantity of output, salad cucumber was the most prominent crop cultivated on high-tech farms, followed by yardlong beans and bitter gourd. The total volume of vegetables raised by the greenhouse farms during the survey year was 865637 kg.

- Total output and productivity (kg per sq. m. and labour hours) were significantly higher for the farms that cultivated salad cucumbers. However, only area productivity was significantly higher among those who cultivated yardlong beans compared to their counterparts.

- The functional relationship between the value of annual vegetable output produced and capital and labour expenditures spent by high-tech farmers showed an increasing return to scale (1.154).

- The cost of fixed assets (greenhouse construction) was the most significant item in the yearly paid-out cost of all greenhouse sizes. Except for extremely small and medium-sized greenhouses, labour costs were the second most important element of A1. Material costs were the second-most important factor for them. As the size of the farm grew from very small to very large greenhouses, the share of interest costs increased.

- The proportion of the estimated interest of owners’ own capital was 12.33 of the B1 cost for all-sized greenhouses. The proportion varied between 17.58 percent (for very small greenhouses) and 10.5 percent (for medium greenhouses).

- For all farms, the average proportion of the imputed value of the owner's own and family labour was 8.51 of the C2 cost. Very small farms had the highest rate, followed by small and medium farms. As the size of the farm grew, the proportion was reduced. To put it another way, very small farms relied heavily on the owners' own and family labour.

- The cost C3 was computed by adding 10 percent to the cost C2. The average yearly cost (C3) of very small farms was one-tenth of the overall average, whereas the cost of very large farms was 2.64 times greater.

- For all-sized farms, the average paid-out cost (A1) per kg of vegetable output was Rs. 61.6 (Rs. 49.8 with subsidy). Small farms incurred the highest costs, while very large farms incurred the lowest costs (small and very small with subsidies). In terms of the average total cost (C3) per kg of output, all farms had an average of Rs. 91.6 (Rs. 78.9 with subsidy). Small farms had the largest costs, followed by very small farms. The amount was reduced as the farm size increased for all other size categories. However, the difference in the average cost was significant for C2 and C3 costs alone, not for A1 and B1 costs (significant for A1, C2, and C3 with subsidies).

- Average costs (A1, B1, C2, and C3) incurred per kg of output by trained (at least one week) farmers were significantly lower than those of the untrained or those trained for less than a week. There was a negative correlation between the duration of the training and the average cost C3.

- A total of 13.86 percent of the annual cost (C3) was subsidized across all greenhouse size categories. Notably, the largest proportion of costs covered by subsidies was observed in the very large greenhouses, accounting for 19.57 percent, followed by the large greenhouses at 16.57 percent. In contrast, small greenhouses received the smallest proportion of cost coverage through subsidies, amounting to just 8 percent.

- The cost-output elasticity of greenhouse farming (with subsidies) was 0.625, indicating an increasing return to scale.

- Most of the greenhouses found markets for their products in local markets, the nearest town, and farm premises. Almost all greenhouse crops fetch higher prices in local markets.

- Yardlong beans were the most wanted crop in the market, followed by salad cucumbers, while brinjal was the least wanted crop. Salad cucumber was the most revenue-generating crop, followed by yardlong beans.

- The average annual revenue generated from one kg of vegetable output was Rs. 47.73. The small greenhouses generated the highest average revenue, while the very large greenhouses generated the least. However, there was no significant difference in the revenue generation of different sizes of farms from one kg of output.

- In the absence of subsidies, only 49 percent of farms made a profit after deducting A1 costs. According to C2 and C3 costs, the proportion fell to 28.5 percent and 21 percent, respectively.

- If A1 cost was taken into account, 67 percent of farms made a profit in the presence of subsidies. According to C2 and C3 costs, the proportion fell to 43 percent and 38 percent, respectively.

- The proportion of loss-makers among very small and very large greenhouses was high compared to other size categories.

- The average annual profit per sq. m. area was Rs. 15 for all-sized farms if the A1 cost without subsidy was taken into consideration. The highest profit was earned by small farms, followed by medium farms, while very small and very large farms incurred losses. For all sizes of greenhouses, the average profit per kilogramme of vegetables grown was negative.

- The average annual profit per sq. m. area was Rs. 84.21 for all-sized farms if the A1 cost with subsidy was taken into consideration. The highest profit was earned by small farms, followed by medium-sized farms. The average profit per kg of vegetable output was negative for all size categories except very small and large greenhouses.

- If other cost measures (C2 or C3) were taken into consideration, the profit per sq. m. area was Rs. 5 for small greenhouses, while for all other sizes it was negative. The average profit from one kilogramme of vegetable output for all size categories was negative, even in the presence of a subsidy.

- However, subsidies play a great role in the profit-making of greenhouse vegetable farms. Even with subsidies, the majority of greenhouses were operating at a loss during the survey year. Higher levels of average costs (both paid out and imputed) and low levels of prices were the primary causes of greenhouse cultivation losses. The majority of greenhouses were used to cultivate conventional crops such as salad cucumbers, yardlong beans, bitter gourds, tomatoes, and so on, which faced stiff competition from open-field products. In Kerala greenhouses, it was very rare to find high-priced crops like coloured capsicum, lettuce, and so on.

- In terms of overall profitability since their inception, only 18 percent of greenhouses have made a profit if the subsidy is not deducted from the cost. Furthermore, there was no statistically significant difference in the proportion of profit earners among greenhouse sizes.

- If subsidies were subtracted from the cost, the percentage of profit-makers rose to 53 percent. Small and very large greenhouses had a higher number of losers than winners, but very small, medium, and large greenhouses had a lower proportion of losers.

- The average payback period for all greenhouses (of those that recovered invested money) was 4.4 years, ranging from 3.4 (small) years to 4.87 years (very large). However, there was no statistically significant difference between the payback periods of farms of different sizes. The minimum and maximum periods of payback were 2 years and 8 years, respectively.

- The average payback period for full-time and part-time farmers was 4.42 and 4.39 years, respectively. This difference was statistically significant, as the actual level of significance was less than 0.5 percent.

- Because the Benefit-Cost Ratio (cost after deducting subsidies) was less than 1 for 45 percent of greenhouses, 1 for 2 percent, 1 to 1.5 for 30 percent, 1.5 to 2 for 8 percent, and above 2 only for 5 percent of greenhouses, the profitability of greenhouse vegetable farming was not satisfactory. All greenhouses had an average BCR of 1.10. Additionally, there was no statistically significant difference in the average BCR between full-time and part-time activities or across greenhouses of various sizes.

- The BCR was less than 1 for 79 percent, equal to 1 for 3 percent, between 1 and 1.5 for 14 percent, and between 1.5 and 2 for 4 percent of greenhouses if the subsidy was not subtracted from the cost. No greenhouses had a BCR greater than 2.

- The contract with vegetable traders, better prices according to the intended level, regular visits of agricultural officers in GHs, farmers' experience in GH farming, doing it as a full-time job, and natural ventilation of GHs were major determinants in classifying a GH as profitable. The latter two were negative determinants (they reduced the probability of a GH falling on the profit side), whereas the others were positive determinants (they improved the probability of falling a GH on the profit side).

- Most of the farmers agreed that it was not profitable to grow vegetables in greenhouses.
- The majority of the greenhouse vegetable farmers opined that the activity did not provide notable employment opportunities to the young educated in the state.
- Despite being protected, 62 percent of the greenhouses had pest attacks on their crops. Only 21 percent of greenhouses, however, frequently experienced insect infestation. When comparing crops grown using organic and non-organic methods, the proportion of pest infestations was higher for the former.
- The majority of greenhouse farmers only used biopesticides to manage pests. 15.74 percent of farmers used chemical and bio-insecticides. It was quite uncommon to use exclusively chemical insecticides.
- Another barrier to greenhouse cultivation was the short lifespan of roofing and covering sheets. Only 19 percent of greenhouses were able to keep them for more than 5 years. The remaining 81 percent of farmers were unable to use them for more than five years. Very large greenhouses had more durability than small greenhouses. The main cause of the sheets' short lifespan was moss clogging.
- The most common way to get rid of moss and fungus that had grown on roofing and covering sheets was to wash the surface of the sheets once a year, but this was an expensive method.
- Only 9 percent of farmers had an environmentally friendly and scientific method for disposing of removed roofing and covering materials. It was only 2 percent for other non-biodegradable waste materials.
- 74 percent of greenhouse farmers had a systematic strategy for getting rid of biodegradable garbage. 17 percent of farmers used the waste as plant

manure, while 57 percent disposed of it in a compost pit to become organic manure.

- Only 6 percent of greenhouses faced water scarcity to irrigate crops.

- In Kerala, crop pollination was a significant barrier to greenhouse cultivation. To deal with the situation, the vast majority of farmers (93 percent) grew self-pollinating crop varieties. For this purpose, 3 percent of farmers kept honey hives inside the greenhouses. The remaining 4 percent of farmers used a hand pollination method to pollinate the blooms.

- Other technical problems with growing vegetables in greenhouses included not getting help quickly from agricultural offices (24.85%), not having enough skilled workers (15.15%), not having enough of the right materials (11.52%), plants burning in the summer (8.48%), and plants rotting in the rainy season.

- 15 percent of greenhouse farmers were unable to find regular buyers for their crops. Local markets were the most prominent source of regular buyers, followed by farm premises and the nearest towns.

- 12 percent of the farmers faced the problem of irregularities in the receipt of revenue from sold crops.

- 21 percent of farmers faced the problem of the return of unsold products from the market. The demand of farmers for higher prices for the crops was the major reason (60%) for the return of products from the market, followed by a lack of sufficient demand (22.86%) and a delay in the marketing of the harvested products (17.14%).

- Nearly all farmers expressed the opinion that since price was the main consideration for consumers, they preferred cheap vegetables from the open field even though they were polluted with chemical pesticide residue. Only 3 percent of farmers disagreed with this statement.

- According to the farmers, the market prices for greenhouse products were low. 54 percent of the farmers said that the market prices were too low. Only 10 percent of farmers thought those prices were attractive.

- In greenhouses, no product has managed to achieve the necessary market price. The only crop whose price came close to meeting the requisite level was green chilli.

- 71 percent of farmers said that the merchants had sought deliberately to lower the price of the goods they had purchased from the farmers.

- Most farmers claimed that there was no assistance from government organisations in marketing the crops produced in the greenhouses. Only 7 percent of farmers expressed a different viewpoint.

- 38.8 percent of greenhouse farmers were indebted, and the proportion of indebted farmers increased as farm size increased from small to very large. However, no farmers in the very small category were in debt.

- Greenhouse farmers' average debt per sq. m. area was Rs. 331.89. Average debt increased as the farm size increased from small (Rs. 158.4) to very large (Rs. 565.21).

- 14 percent of farmers experienced a delay in the disbursement of subsidies. The provided subsidy was insufficient for 52 percent of farmers.

- Subsidies to cover recurring costs are available to less than half of farmers. It was 50 percent for medium and very large farms and 33.33 percent for large farms. Only one farm was in the very small category, and none of the small farms received subsidies for this purpose. The average recurring expenditure subsidy was Rs. 135.5 per sq. m., and it rose as the size of the farm increased.

- In Kerala, crop and greenhouse insurance were incredibly uncommon. Insurance covered only 1 percent of greenhouses and 2 percent of the crops grown inside. Farmers were reluctant to insure their greenhouses and crops for a number of reasons, including a lack of knowledge and a lack of appropriate insurance programmes. Due to the dearth of insurance, many of the greenhouses that were damaged in areas like Thiruvananthapuram, Kollam, and Alappuzha due to Cyclone Ockhi were unable to resume cultivation and had to end this initiative.

8.3 Major Recommendations and Policy Implications

- Because of the limited number of hi-tech facilities used, greenhouse vegetable cultivation in Kerala is a semi-technical farming activity. To make them high-tech, subsidies should depend on how many high-tech features farmers put in their greenhouses.
- The replacement of roofing and covering sheets after a few years of use was a costly activity. Therefore, a supplementary subsidy should be given to the farmers at the time of roofing and side covering replacement.
- Because labour costs (both paid and imputed) are very high in greenhouse cultivation, labour-saving techniques should be implemented, particularly during planting and harvesting. As greenhouse products face competition from open-field products, branding of the products to easily identify the greenhouse products shall be done.
- Farmers should use succession planting techniques in greenhouses, especially in medium, large, and very large greenhouses, to make sure they have a steady supply of crops. The relationship between agricultural offices and greenhouse farmers should be strengthened in order to provide more timely support and advice, as many farmers have expressed dissatisfaction with the lack of such a relationship.
- Instead of promoting mass farming, a class farming strategy should be followed in greenhouse farming. Only those with dedication, a willingness to

work hard, and a genuine interest in high-tech farming will be eligible for greenhouse subsidies.

- Government-supported marketing facilities should be given to greenhouse farmers to ensure reasonable revenue. Furthermore, this helps them escape from the exploitation of traders in the market.
- Farmers should be encouraged to insure their greenhouses and crops inside to avoid heavy losses due to natural calamities like cyclones.
- Farmers should cultivate high-value vegetables like coloured capsicum, lettuce, violet cabbage, cherry tomatoes, zucchini, celery, leek, bok choy, etc. instead of conventional crops like the yardlong bean, salad cucumber, brinjal, etc., to fetch higher prices and, consequently, higher revenue.

8.4 Implications for Further Research

As this study was explorative in nature, the researcher has tried to find the extent, production and productivity, economic viability, and major challenges of high-tech vegetable farming in greenhouses in the state of Kerala. However, there is enough scope for further research in this area.

1. A comparative study of high-tech vegetable cultivation in Kerala with that of other states of India
2. Comparing High-Tech Greenhouse Vegetable Farming Practices in India to Global Leaders: A Comparative Analysis for Enhanced Agricultural Productivity.
3. Evaluating the Economic Viability of Implementing High-Tech Floriculture Practices in Kerala for Sustainable Agricultural Growth.
4. Conducting a Cost-Benefit Analysis of High-Tech Farming Versus Conventional Open-Field Farming: Assessing the Economic Efficiency of Modern Agricultural Practices.

8.5 Conclusion

Kerala possesses significant potential for high-tech vegetable cultivation in greenhouses. Factors such as high demand, a persistent gap in domestic production and consumption, and the cyclical nature of climate-driven production underscore the promise of this agricultural method. It is worth noting that successful implementations of greenhouse farming can be found in countries like Israel, the Netherlands, Spain, China, as well as in Indian states like Karnataka and Himachal Pradesh. With high expectations, Kerala ventured into greenhouse farming, commencing in the fiscal year 2009-10 and bolstered by substantial subsidies. Consequently, the sector experienced remarkable growth. However, after a few years of rapid expansion, the industry faced stagnation. Nearly a decade after its introduction, it has become evident that greenhouse farming has not had a significant impact on the state, neither in terms of the land area dedicated to vegetable cultivation nor in terms of overall production.

While greenhouse farming boasts higher productivity compared to traditional open-field production, the high production costs and the inability to compete with more affordable alternatives in the market have impeded its progress. The profitability of greenhouse farming has proven to be a challenge across various aspects, irrespective of differences in greenhouse size, types, cultivation methods, and time management.

The lack of profitability can be attributed to a combination of technical and financial factors. Technical issues included the deterioration of greenhouse glazing sheets within a few years due to the accumulation of moss and dust, challenges in managing plastic waste, pest infiltration, and issues related to crop pollination. These technical challenges were further exacerbated by economic constraints, including substantial debts, suboptimal pricing of products, exploitation by traders, competitive pressures from more affordable alternatives, inadequate subsidies, and the absence of insurance.

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APPENDIX-1

Q. ID…………………….

DEPARTMENT OF ECONOMICS
ST. JOSEPH'S COLLEGE (AUTONOMOUS) DEVAGIRI CALICUT

PhD work of Ashraf Panancheri, Research Scholar

Economics of High-tech farming in Kerala: An Explorative Analysis of Greenhouse Vegetable Farms

Schedule to collect information from Greenhouse Farmers

Name of the Investigator
Ashraf Panancheri

Name of the Supervisor
Dr. Sanathanan Velluva

Block 1: **General Information of the Greenhouse Vegetable Farmer**

1. Name and contact Number:
   ……………………………………………………………
2. Mail ID (optional) :

3. Individual / Institution / Co-operative Unit
4. If individual Gender: Male/ Female/TG
5. Place:……………………………………………… Block: ………………………… District:………………………….
6. Educational qualification of the farmer:

Up to SSLC	+2/PDC	Diploma	Graduation	Post Graduation	Professional Degree

7. Your age in years ………………………..

8. Your religion (please tick):

Hindu	Christian	Islam	Others	Atheist

9. You belong to:

SC	ST	OBC	General

10. Did you get training in greenhouse farming:

Yes	No

If yes, Duration in weeks…………………

11. Is greenhouse farming your full-time activity? | Yes | No |

if no,

a. What is your main occupation (please tick):

Govt. or govt. aided job	Business	Professional	self-employed	Retired from service	Open field Farming

12. Your total land holding (in Cents)

Paddy	Coconut	Rubber	Spices	Vegetables	others

II -General Features of your Greenhouse/ GH

13. Name of Greenhouse (if any) …………………………………………
14. Area of greenhouse for vegetable cultivation in square meter………
…………………

15. Physical appearance: (Please tick)

Gable type	Saw tooth type	Other specify ………………..

16. Existence: (Please tick)

Attached with any building	Exists separately	Gutter type	Other……..

17. Type of covering material used (Please tick the relevant box):

i- Polyethylene	ii- Poly ethylene UV-resistant	iii- Fiberglass	iv-Tedlar coated fiberglass
v- Double strength glass		vi- Polycarbonate Sheet	vii- Any other material (specify)………………..

18. Material used for structure:

GI	Wood	Bamboo	Others (specify)……………………

19. Whether fully covered with net: | Yes | No |
20. Whether shade net is used: | Yes | No |
21. Whether your greenhouse is naturally ventilated: | Yes | No |
22. Which of the facilities are used in your greenhouse multiple response allowed)

Fan	Pad	Fogger	Sensors	Automated system of heat control	Automated irrigation system

23. Plants are planted in:

Soil made ready on surface	Poly bags	Raised beds	Others …………

24. Soil used for planting plants:

Soil available locally	Special soil purchased for the purpose	Artificial materials prepared for the purpose	Others …………

25. Direction of greenhouse:

North- south	East- west	Others Specify………………

26. For your greenhouse crops you use:

i) Both chemical fertilizers and pesticides	ii) Chemical fertilizer and organic pesticides	iii) Organic fertilizer and chemical pesticides	iv) Only organic manure and organic pesticides

III Nature of cropping under greenhouse (please tick)

27. Which of the crops you cultivate (multiple response allowed):

Tomato	Capsicum	Yard long bean	Cabbage	Cauliflower	Salad cucumber	Green chilly	Spinach	Bitter gourd	Brinjal	Others specify ………………

28. Nature of cropping:

Single crop	Multiple crops in mixed form	Multiple crops in separate area under same greenhouse.

29. Do you practice vertical farming?

Yes	No

If yes, for which crop…………………………….

30. Where do you get seeds for greenhouse cultivation?

Your own	Local markets	Krishi bhavans	Companies in India	Imported from foreign companies

If from companies: name of the company……………………….

31. How many seasons do you cultivate vegetables under greenhouse in a year:

Crop	Tomato	Capsicum	Pea	Cabbage	Cauliflower	Salad cucumber	Green chilly	Bitter gourd	Brinjal	Others specify …………… …………… ……………
Number of seasons in a year										

32. Do you apply any idea of your own in cultivation?

Yes	No

If yes, in connection with which of the following? (Please tick, multiple response allowed)

i) Structure ii) Soil iii) Seeds iv) Manures and fertilizer

v) Control of pests and plant diseases vi) Cropping mix vii) Packing of the product

viii) Marketing of the product ix) Crop management x) Irrigation xi) Pollination

xii) Control of heat and humidity in the greenhouse

IV Cost of cultivation under Greenhouse

a. How much did you spend for the construction of greenhouse? …………
b. Cost incurred for structure……………………………………………….
c. Cost of covering materials incurred: …………………………………….

d. Cost of labour for the construction of greenhouse:………………………
e. Other costs for construction of greenhouse……………….. …………….

Item	Amount
i. Hired human labour	
ii. Animal labour	
iii. Machine labour (for leased machine)	
iv. Seed/ seedlings	
v. Manure and Chemical fertilizers	
vi. Plant protection (pesticide/fungicide etc)	
vii Irrigation cost	
viii. Land tax	
ix. Repair and maintenance charges of implements, machinery and structure	
x. Interest on working capital (Rate: ……..) Amount:	
xi. Other expenses	

33. Cultivation cost for a year:

34.

Annual Interest on fixed capital:	Rate: …….	Amount:

35.

Annual Interest on land value:	Rate: ….	Amount:

36.

Imputed value of household labour (approximate value of your own and family members' labour for which payment is not done)	Amount:

37.

Imputed value of your other resources (approximate value)	Amount:

38. Annual managerial cost: ……………..

39. Did you take loan for GH cultivation

Yes	No

40. If yes, how much………………..
41. For GH construction………………….
42. For meeting recurring expenses…………..
43. For other purposes…………………….
44. Source of loan

Friends and relatives	Scheduled banks	Cooperative banks	Non-banking institutions	Local money lenders

45. Did you get subsidy to construct Greenhouses: Yes/ No
For GH construction……………. To meet recurring expenses……………..

V- Yield of greenhouse crops

46. Total yield of different crops in the last year:

Crop	Tomato	Capsicum	Yardlong bean	Cabbage	Cauliflower	Salad cucumber	Green chilly	Spinach	Bitter gourd	Brinjal	Others specify …………… ……………
Yield in a year (in kgs)											

47. Total revenue from different crops in the last year:………………….

Crop	Tomato	Capsicum	Yardlong bean	Cabbage	Cauliflower	Salad cucumber	Green chilly	Spinach	Bitter gourd	Brinjal	Others specify …………… ……………
Yield in a year (in kgs)											

48. During which season do you get high yield:

Rainy	Winter	Summer

49. Based on your experience and considering yield;

Which crop is most suitable for greenhouse cultivation………………………………
Which crop is least suitable for greenhouse cultivation………………………………

50. Considering the plant diseases, which crop is most suited? ………………………

Which crop is least suited? ………………………………….

51. When do you get the highest return from greenhouses?

Initial years	After a few years	Last years	No significant difference

VI- Marketing of Greenhouse Products

52. Where do you sell your farm products (please tick):

In farm premise	Local markets	Nearest town	Export to other states	Export to other countries

If export, major destination of your product…………………………

53. Do you have any contract with the merchants for buying your product? | Yes | No |

54. From which market do you get higher prices for your product (please tick):

From farm premise	From local markets	From nearest town	From export to other states	From export to other countries

55. Which one is the most wanted greenhouse crop in the market?......................................

56. Which one is the least wanted greenhouse crop in the market?..

57. Do you have cold storage facilities to keep the product until sent to the market? | Yes | No |

58. Do you pack the product before sending it to the market? | Yes | No |

59. Do you have regular customers to buy your product? | Yes | No |

If yes, in which market ((please tick, Multiple responses allowed)

In farm premise	In local markets	In Nearest town	In other states	In other countries

60. Do you market your product with a particular brand name?

Yes	No

61. When do you get the payment for your products?

Daily	Weekly	Monthly	Others :…………………

62. Do you face the problem of default in payments from your buyers?

Yes	No

63. If yes, how do you tackle the problem of default?

Through contact and request	Involvement of any third party	Legal action	Any other method …………………

64. Do you face the problem of return of unsold product from the market?

Yes	No

65. If yes, the reason for return (please tick):

Delay in marketing	Lack of proper packing and preservation	Lack of sufficient demand	Your demand for higher price	Low quality of product

66. Do you advertise your product among customers?

Yes	No

67. If yes, media of advertisement (please tick).

Printed Notice	Local newspaper	Local TV channels	National TV channels

For the questions from 69 to 74 please give marks as given below

1 mark if perfectly disagree	**2** marks if disagree	**3** marks If you are indifferent	**4** marks If agree	**5** marks If perfectly agree

68. There is always a sure market for greenhouse vegetables
69. Mostly, traders try to reduce the price of vegetables supplied by you

70. You get higher prices for greenhouse vegetables compared to products from open field.

71. Competition in the greenhouse vegetable market is high

72. Farmers' associations help you to market your products

73. People usually prefer low-priced vegetables even if it is contaminated with chemicals.

VII - Overall economic performance of Greenhouse vegetable farming

74. Total Revenue from your greenhouse in the last year. …………………….

75. How many days of human labour spent for cultivation in your greenhouse in the last year other than yours and family members……………………………….

76. How many days' works has been done by you and family members in greenhouse farming activities for which payment is not recorded? ....

77. Are you satisfied with the economic performance of greenhouse vegetable farming

Yes	No

78. If no, what is the major reason for dissatisfaction ((Please tick, multiple responses allowed)

Profit is not sufficient	Marketing of the crop is difficult	The initial cost is very high	Difficulty in getting required materials	Lack of support from govt.	Diseases and insect attack	Any other issues

Respond on the following statements by giving mark

1 mark if perfectly disagree	**2** marks if disagree	**3** marks If you are indifferent	**4** marks If agree	**5** marks If perfectly agree

79. You are happy in entered to greenhouse cultivation

80. Greenhouse vegetable farming is not a good remunerative activity

81. Greenhouse vegetable farming is a high risky activity

82. Greenhouse farming is a good employment opportunity to young unemployed

VII Major Constraints of Greenhouse vegetable farming:

83. How many years the covering sheet of greenhouse lasts…………………

84. What do you do with removed greenhouse covering sheets after the use?

Keep in the farm	Bury in the field	Burn	Dump with garbage	Handover to scrap vendors	Handover to LSG for recycling	Any other ……………………

85. What do you do with the plastic threads, tags, plastic bags, pipes, and ribbons after use?

Keep in the farm	Bury in the field	Burn	Dump with garbage	Handover to scrap vendors	Handover to LSG for recycling	Any other ……………………

86. What do you do with degradable wastes of your greenhouse?

Bury in the farm field	Put in the compost pit in the farm	Burn	Put in the public dust bin	Handover to LSG* for disposal	Any other …………………

87. Any insect attacked your greenhouse crops at any time? Yes | No

If yes, how did you control

Application of chemical pesticides	Application of Organic Pesticides	Application of both chemical and organic pesticides	Naturally controlled without any pesticides

88. Is the insect attack usual in your greenhouse Yes | No

89. How did insect attack affect your return?

Heavy loss in revenue	Moderate loss in revenue	Small loss in revenue	No loss in revenue

90. Your main source of water for irrigation?

River/Canal	Open well/pond	Bore well	Public water supply

91. Do you face water shortage during summer? | Yes | No |

92. Being covered with insect proof materials how do you solve the pollination problem of plants?

i-By Cultivating self-pollinating varieties only	ii-By keeping honey bees	iii-By using vibrators	iv-By using fans
v-Any other method (specify)	……………………………………………..		

93. Do you get timely advice from agricultural offices in connection with the construction and maintenance of the greenhouse? | Yes | No |

94. Did you get the subsidy for the construction of the greenhouse on time? | Yes | No |

95. Did you take loan for the greenhouse? | Yes | No |

If yes, amount: ……………..

96. Was there any delay in the sanction of loans? | Yes | No |

97. Financial institution who sanctioned loan for the greenhouse?

……………………………………………………..

98. Are your greenhouse insured? | Yes | No |

99. Are your greenhouse crops insured? | Yes | No |

100. Do you face a shortage of skilled labourers for doing farm operations in the greenhouse? | Yes | No |

101. Do you face the problem of not getting essential materials for your greenhouse cultivation? | Yes | No |

102. Do you face the problem of burning the plants during the summer due to heavy temperatures? | Yes | No |

103. Do you face the problem of rotting the vegetable plants during the rainy season? | Yes | No |

104. Do you face the problem of moss clogging on the covering material which prevent the entry of proper sunlight? | Yes | No |

105. If yes, how do you solve the problem?

Frequent changing of roofing sheets	Washing of the roofing sheets	Any other methods ………………..

VIII Future Plan

106. Which of the following do you like to do in the future?
   - i) Will keep the area of cultivation constant.
   - ii) Will increase the area of cultivation.
   - iii) Will reduce the area of cultivation.

107. Your opinion about the prices of vegetables existing in the market (for your products)

Attractive	Sufficient	Insufficient

108. Considering the cost of cultivation, the minimum price that must be secured for various vegetables cultivated by you.

Crop	Tomato	Capsicum	Yardlong bean	Cabbage	Cauliflower	Salad cucumber	Green chilly	Spinach	Bitter gourd	Brinjal	Others specify …………… ……………
Yield in a year (in kgs)											

109. Do you think GH vegetables are superior than that of the open field?

Yes	No

If not, the reason………………………

110. What is your opinion about the availability and prices of the following inputs?

Input/ Materials	Availability		Price			Any other
	Sufficient	Insufficient	High	Usual	Low	
Structure						
Covering sheet						
Seeds and seedlings						
Fertilizers						
Pesticides						

Farms equipment*						
Farm workers						

*Fan, Pad, Fogger, Vibrator, Sensors Irrigation equipment

111. Is subsidy given by the government Sufficient | Yes | No |
112. Do agricultural officers visit you to guide about greenhouse agriculture?
     If yes, how many times in a month approximately

113. Do you have hydroponic system of cultivation? | Yes | No |
114. Do you have aquaponics system of cultivation | Yes | No |

Appendix 2

Agricultural Cost Concepts

(*Economics And Statistics*, *Ministry of Agriculture*, *Government of India*)

The cost of cultivation of vegetables crops was worked out by using various cost concepts defined below: Cost A1: It includes

1. Value of hired human labour
2. Value of hired and owned bullock labour
3. Value of hired and owned machine labour
4. Value of seed (both farm seed and purchased)
5. Value of manures (owned and purchased) and fertilizers
6. Depreciation
7. Irrigation charges
8. Land revenue
9. Interest on working capital
10. Miscellaneous expenses

Cost A2: Cost A1 + rent paid for leased-in land

Cost B1: Cost A1 + interest on fixed capital (excluding land)

Cost B2: Cost B1 + rental value of owned land + rent for leased-in land

Cost C1: Cost B1 + imputed value of family labour

Cost C2: Cost B2 + imputed value of family labour

Cost C3: Cost C2 + 10 per cent of cost C2 as management cost.