ECONOMIC FEASIBILITY OF VEGETABLE PRODUCTION UNDER POLYHOUSE CULTIVATION

By

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(2013-11-165)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Economic feasibility of vegetable production under polyhouse cultivation"** is a bonafide record of research work done by me during the course of research and that the thesis has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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To Arun,

For his patience, faith and encouragement

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Introduction

1. INTRODUCTION

Agriculture is an outdoor activity or open field production of crops since prehistoric times. Open field crop production is climate and weather dependent. For each of the crops there are ecological optima for attainment of its production potential and abiotic and biotic factors which govern this crop production potential and quality of produce. Deviations from these environmental and climatic conditions result in yield loss both in terms of quality and quantity of the produce. The magnitude of impact of climate and weather on productivity and quality of produce is more likely observed in horticultural crops. Among the major constraints in production of horticultural crops are temperature extremities, duration and quality of sunlight, deficiency or excess of water, atmospheric moisture (relative humidity), nutrient deficiency and biotic stresses such as weeds, pests and diseases. To overcome these major hurdles of production, an optimal climatic condition could be created by controlling the crop microclimate with the help of different protected structures or methods or devices; and such cultivation under controlled environmental condition is termed as protected cultivation and the protected structures are generally known as greenhouses.

The fundamental principle involved in protected cultivation is the 'greenhouse effect' – involving heating of cropped area using sunlight, ventilation for cooling and air carbon dioxide regulation. The protected structure reflects back 43% of solar radiations incident upon it allowing transmittance of photosynthetically active solar radiation which increases the photosynthetic efficiency of crops grown under it. The ultraviolet radiations damaging the crops are absorbed by the cladding material (glass/ polythene etc.). This facilitates better crop growth and yield under protected structures. The sunlight admitted inside the structure is absorbed by the crop, floor and other objects inside the structure which in turn emit long wave infrared radiations leading to rise in temperature inside the structure. During low temperature situations, this raise of temperature inside the protected structure is its most important function for enhancing crop growth and yield. During summer the inside temperature rises higher than the optimum level necessitating lowering of temperature to below 35^0C through evaporative or ventilation cooling.

Today, around 20 million ha is under different forms of protected cultivation the world over. The Netherlands has a long tradition of protected cultivation under glasshouses for growing flowers and vegetables with the most advanced and automated technologies. At present, an area of around 10,000 ha is estimated as under protected cultivation and most of these are climate-controlled glasshouses with soilless cultivation. Among the Middle East countries, Israel has the largest number of Hi-tech greenhouses being used for production of export quality cut flowers and vegetables and is also the largest exporter of cut flowers and vegetables grown under protected conditions. In Europe, highest area under greenhouses coverage is in Spain followed by Italy. The countries which are located around Mediterranean region like Morocco, Algeria, Egypt, Greece, Italy, Jordan, Portugal, Spain, Syria and Tunisia cover an area of about 2 lakh ha under greenhouses; 20,000 ha under glasshouses and 1 lakh ha under low tunnels (Paroda, 2014).

In Asia, China pioneered in protected cultivation in the early 1990s. China has a large area under protected cultivation, making it the largest producer of vegetables in the world. The total area covered under plastic covered greenhouses in China is 2.5 million ha (85 % of the worldwide coverage). Japan is the next leading country, producing fruits, vegetables and cut flowers under protected structures, covering an area of 52,000 ha. South Korea, Kuwait and UAE have sizable area under protected cultivation.

India, at present is the second largest producer of vegetables in the world. Horticulture is one among the major forms of cultivation in India. However, protected cultivation occupies only 0.23 percentage of total area under horticultural crops in India (NHB, 2012). Tomato, capsicum, cucumber and melons are the major crops grown under protected cultivation. With the coordinated efforts of Central and State Governments, protected cultivation is gaining popularity in India. The states and union territories that have adopted protected cultivation have increased from nine states in 2007 to 30 states and union territories in 2012. The total area under protected cultivation has increased by an extend of 49.19 per cent during the period 2007 – 2012 (Sidhu, 2014).

Kerala, characterized by tropical humid weather with intense rainfall and humidity makes it an unfavourable environment for year round production of vegetables. With a total production of 8.25 lakh tonnes of vegetables from a total cultivated area of 41,262 ha, the per capita availability of vegetables cultivated in Kerala is far below the recommended per capita consumption (Economic Review, 2014). Limitations of land holdings, market price fluctuations, perishable nature of crops, constraints in marketing, erratic climatic conditions, high labour cost etc. are the problems faced by conventional vegetable cultivation in the state. In this context, protected cultivation offers a new dimension to produce more from a limited area. Naturally ventilated polyhouses and rain shelters are recommended protected cultivation structures for Kerala. Recently, the Kerala Agricultural University has also developed an ad-hoc package for protected cultivation of vegetables.

Even though the Government of Kerala and State Horticulture Mission have implemented several programmes to promote polyhouse technology all over Kerala; its suitability and economic feasibility in the state have been less explored so far. Any efforts at analyzing the status of polyhouse cultivation in Kerala would get restricted due to scarce and often unreliable nature of statistical information on polyhouse cultivation in the state. The present study aims to analyse the economic feasibility of vegetable production under polyhouse cultivation in the major polyhouse cultivating areas of Kerala and to draw a comprehensive idea on the realistic representation of polyhouse cultivation scenario of the state.

Specific objectives of the study

- To study the economics of production of vegetables under polyhouse condition
- To compare the profitability and resource use efficiency in polyhouse and open field cultivation
- To study the factors which influence the decision making in adopting polyhouse cultivation
- To enlist the problems faced in polyhouse cultivation

Limitations of the study

The study involves a comprehensive comparison of polyhouse and open field cultivation of vegetables covering the socio economic, cultural and economic aspects. Hence it would be advantageous to get the same crops cultivated in polyhouse as well as in open field. But, polyhouse cultivation being a novel technology, its adoption in the cultivation of major vegetable crops of Kerala is restricted. Getting adequate sample size of the same crops cultivated both in polyhouse and open field was a challenge. . Hence comparative part of the study had to be limited to the crop cowpea, as it was the only major crop found cultivated both in polyhouse and open field in the study area. The study was conducted pertaining to data on the central and high range zones of Kerala. As Kerala's socio economic and climatic situations vary widely, caution should be exercised while generalizing the results. In the absence of specific temporal data on cash flow of polyhouse cultivation for its entire lifespan, certain assumptions were made while carrying out the capital productivity analysis – the lifespan of polyhouse was assumed to be 10 years and the income stream of polyhouse cultivation was assumed to be uniform over the entire lifespan.

Care has been taken to avoid response biases and cross verified the facts and figures to the extent possible, to make the study results as valid as possible.

Review of Literature

2. REVIEW OF LITERATURE

A review of the studies closely related to the present research work is attempted in this chapter. Extensive search of literature was done for choosing the appropriate analytical methods and finalizing the variables. Previous studies on the economics of vegetable cultivation in polyhouse and in the open, resource use efficiency in vegetable cultivation in the open and in polyhouses are presented under the following sub headings.

2.1 Economics of vegetable cultivation

2.2 Resource use efficiency

2.3 Production technology in polyhouse cultivation

2.4 Problems and prospects of polyhouse/protected cultivation

2.5 Adoption of protected cultivation

2.1 Economics of vegetable cultivation

Srivastava (1993) made an attempt to examine the economics of vegetable production in the sub areas of Patna. The highest productivity (275.23 q/ha) and Capital- output ratio (1:2:84) was recorded in case of cabbage and cauliflower. Even though highest net returns per hectare could be realized in cowpea, the cost of cultivation per hectare was very high.

Peter (1995) reported that the cost of cultivation of chillies increased over time due to the high cost of labour and increased use of plant protection chemicals in Kerala. The hired human labour accounted for an average 20 per cent of the total cost of cultivation. The cost of cultivation was Rs. 13, 287 per hectare and Rs. 13, 762 per hectare on small and large sized farms respectively recording an average of Rs. 13,528 per hectare.

A study of seasonal vegetables in Kullu conducted by Thakur *et al* (1997) revealed that the total cost of production was higher for tomato followed by cauliflower, cabbage and capsicum. The net profits were Rs. 145961, Rs. 73900, Rs. 68246, Rs. 46266 and Rs. 44777 per hectare from tomato, cauliflower, cabbage, capsicum and pea respectively.

Radha and Prasad (2001) made an attempt to study economics of production and marketing of vegetables in Andhra Pradesh. The results indicated that the cost of cultivation was highest for tomato with Rs.28055 per hectare, whereas the net return was highest in cauliflower (Rs.55792 ha^{-1}) followed by tomato (Rs.49758 ha^{-1}). The cost benefit ratio was highest for cauliflower (1:2.90) and lowest for bhindi crop (1:0.28).

Singh *et al.* (2005) reported that gross income, net income and benefit: cost ratios were found higher under protected condition as compared to open field condition in cucumber, summer squash and okra in a study conducted to examine the effect of protected and unprotected conditions on biotic stress, yield and economics of spring summer vegetables at Precision Farming Development Centre, IARI, New Delhi. Even though the cost of cultivation was found low under open field condition, protected condition was found more remunerative on account of 3 to 4 fold increase in marketable yield, early harvesting, better quality produce and higher market price.

Engindeniz and Tuzel (2006) in the economic analysis of organic greenhouse lettuce production in Turkey suggest that organic green house lettuce production is an economically viable alternative for growers, although the initial and total costs of organic lettuce production were higher compared to conventional production. This was compensated by the higher price of organic lettuce which was 3.5 fold higher than conventionally produced lettuce. It was estimated that the total net return varied between \$ 0.376 and \$ 0.901 m^{-2} for organic production whereas, net returns in case of conventional lettuce production varied between \$ 0.155 and \$ 0.650 m^{-2} in the same region.

In a study on precision farming technology in resource-poor environments conducted in the Dharmapuri district of Tamil Nadu, Maheswari *et al.* (2008) reported that adoption of precision farming leads to about 80 per cent increase in yield in tomato and 34 per cent in brinjal along with an increase in gross margin by 165 per cent in tomato and 67 per cent in brinjal production as compared to conventional cultivation.

Murthy *et al.* (2009) in a study examining the economic viability of production of capsicum and tomato in naturally ventilated polyhouse at IIHR, Bangalore categorizes three different types of costs for polyhouse cultivation of vegetables *viz*, fixed cost, annual variable cost and seasonal variable cost. They also reported that cultivation of capsicum in polyhouse was highly feasible as reflected in higher values of NPV, BCR and IRR with less than two years of payback period. Whereas production of tomato in polyhouse was found not feasible by examining the project appraisal factors NPV, BCR, IRR and payback period

A research on the performance of sweet pepper (*Capsicum annum*) varieties and economics under protected and open field conditions in Uttarakhand conducted by Singh *et al.* (2011) revealed that maximum gross returns (349.68/m^2), net returns (281.45/m^2) and benefit: cost ratio (5.5:1.0) was observed in sweet pepper cultivated in polyhouse, followed by poly-tunnel and plastic-mulching treatments. All the observations were found lower under open field condition.

While studying the protected v/s open field conditions on insect pest incidence to minimize insecticide application for quality production of high value horticultural crops at CPCT, IARI, New Delhi, Singh *et al.* (2012) reported that the marketable fruits production and net income were found maximum under polyhouse than open field and concluded that cultivation of highly insect-pest susceptible vegetables and fruits inside polyhouse is beneficial.

Prabhakar *et al.* (2012) in a study on scope and potential of high value vegetable production in greenhouse point out that greenhouse were expensive to build. An artificially ventilated greenhouse of 1 acre may cost Rs. 30-35 lakhs to erect and equip; whereas low cost naturally ventilated green houses of the same size can be constructed for Rs. 6-8 lakhs. In order to keep the maintenance cost as minimum as possible, areas with minimum extremities of weather conditions are ideal for year round vegetable production. The production cost will be high in regions with hot summer conditions as the cost of cooling is quite high.

Singh (2012) while discussing on protected cultivation technologies for higher profitability and livelihood security suggests that protected cultivation has a very good potential in peri-urban agriculture since it can be profitably utilized for the production of high value crops like cherry tomato, capsicum, salad cucumber, healthy and virus free seedlings in an agri-entrepreneurial model.

Bala (2013) in a study conducted among the polyhouse vegetable farmers of Himachal Pradesh estimated that a farmer could have net returns up to Rs.1.42 lakhs per annum from a 500 sq. m. polyhouse after accounting for an 80 per cent total cost as subsidy by the Government of Himachal Pradesh. It is also stated that, a manifold increase in the resource-use efficiency in crop production can be obtained through protected cultivation when compared with the open field conditions.

The study by Kaddi *et al.* (2014) to analyze the comparative economic advantage for hybrid seed production of cucumber Pant Shankar Khira 1 under naturally ventilated polyhouse, insect proof net house and open field condition revealed that the insect proof net house was more profitable followed by open condition and naturally ventilated polyhouse was found uneconomical because of its high initial investment.

Kishore *et al.* (2014) while studying on the sequential vegetable production under protected condition in temperate humid regions of East Sikkim reported that the production cost of vegetables under polyhouse was about 1.5 times higher than that of open field; however return was about two times higher.

Sanjeev *et al.* (2014) in the study 'Economic viability of cucumber cultivation under NVPH (Naturally Ventilated Polyhouse)' reveals that the value of economic inputs along with subsidy component imparted by the Government of Gujarat in the cultivation of cucumber in naturally ventilated polyhouse could improve the benefit: cost ratio to a tune of 2.03 with 65 per cent subsidy from an earlier non subsidy situation with benefit: cost ratio of 1.36.

2.2 Resource use efficiency

Sharma *et al.* (1992) examined the resource use efficiency and profitability of vegetable farming in Himachal Pradesh. The study indicated that vegetable crops occupying 40.57 per cent of the total cropped area accounted for 52 per cent of the gross returns whereas cereals covering 42.48 per cent of the gross returns. This trend indicated that vegetable crops were yielding high returns than cereals. The regression analysis related elasticity coefficients for human labour was positively significant in case of all the vegetable crops with an exception to chillies. Increasing returns to scale observed for potato, peas, cauliflower and brinjal point towards intensive use of inputs for obtaining higher income from the vegetable crops.

Pascale and Maggio (2005) of the University of Naples Federico, Italy reported that protected cultivation is normally characterized by greater water use efficiency and had attributed reduced potential evaporation (reduced solar radiation, less wind and greater air humidity); higher productivity (better control of climatic parameters and plant diseases); application of more advanced irrigation technology (drip irrigation, reuse of drainage water) as the reasons for the same.

A study conducted by Mishra *et al.* (2010) of Defense Institute of High Altitude Research (DIHAR) reported that in high altitude cold arid regions like Ladakh, with very harsh climate and a short agriculture season, the introduction of protected cultivation enabled the growing of vegetables throughout the year in the hostile climates. By using various types of greenhouses, DIHAR had grown 78 different types of vegetables in a single season during 2007.

While discussing on the prospects of vegetable crop improvement for greenhouse cultivation, Singh *et al.* (2012) emphasised on the technology of 'plasticulture', the practice of using plastic for commercial horticultural production. Various applications of plastics in horticulture include protected cultivation, plastic mulching, plastic lining etc. It is also stated that plasticulture improves the economic efficiency of production system and helps in efficient water and energy management.

Pandey *et al.* (2012) while discussing the need for revitalizing Indian agriculture and high tech interventions as a solution, points out the sustainable agricultural promotion innovative technologies practiced in countries like Japan, Netherlands and Israel. By the use of many modern agricultural practices such as high tech farming and protected cultivation, these countries have achieved higher profitability levels by minimal use of external inputs and thus regenerating the internal resources more effectively, or by the combinations of both.

Studies conducted by Sabir and Singh (2013) indicated that efficient water usage can be achieved through protected cultivation as compared to open field conditions. Drip irrigation technology used in greenhouse production systems not only helps in using water efficiently but also can be responsible for reducing diseases that develop in rather moist conditions. Fertigation allows for precise and homogeneous application of nutrients in the active root zone area ensuring high potential efficiency

2.3 Production technology in polyhouse cultivation

Kumar and Srivastava (1997) studied the influence of plastic coverings on the temperature and relative humidity under low plastic tunnels in tomato field during the winter-spring season. The minimum and maximum temperature and relative humidity were significantly increased inside the polyethylene tunnels of all gauges viz. 200, 300 and 400 as compared to no cover in all the weeks. The 300 and 400 gauge plastic always proved superior to lower gauge. The 100 perforations/ m^2 always showed highest minimum temperature whereas, maximum temperature continuously from 50 perforations to 150 perforations. In most of the weeks, perforations had no significant effect on relative humidity.

Production of off-season tomato crop under net house conditions conducted at the Vegetable Research Farm, PAU, Ludhiana, by Cheema *et al.* (2002) revealed that net house cultivation has extended the fruit availability of tomato. Negligible fruit damage (1.43%) by *Spodoptera litura* was recorded after following non-insecticidal (non-chemical) methods of control. While, incidence of *Helicoverpa armigera* and aphid, *Aphis gossypii* was nil which otherwise are serious pests of tomato crop in open conditions. These studies have offered the possibility of raising off-season crop of tomato and enhancing the fruit availability period by using non-chemical methods of pest control.

High incidence of insect-pest (above threshold level) was observed under unprotected condition while saving of insecticides and money was higher under protected condition as compared to unprotected condition in cucumber, summer squash and okra. The average marketable fruit yield was found maximum (kg/plant) under protected condition than under unprotected condition due to the minimum incidence by insect-pest and diseases (Singh *et al.* 2005).

Singh and Asrey (2005) studied the performance of tomato and sweet pepper under unheated (naturally ventilated) green house. The production of tomato and sweet pepper under medium cost green house was found to the tune of 93.2 and 76.4 t/ ha respectively. It was of excellent quality as compared to outside where the crop could not survive due to prevailing low temperature. The study conducted at Hariyana has also indicated that cultivation of tomato and sweet pepper under green house would not only help in getting higher productivity but also fetch better returns.

Sood and Sharma (2006) in a study to evaluate the performance of cucumber under varying environmental conditions in the cold desert areas of North-Western Himalayas reported that the protected environment had distinct superiority and significantly higher number of fruits, fruit weight, length, diameter and increase in yield by 167.6 per cent as compared to open environment.

While studying the performance of leafy vegetables under protected environment and open field condition of Haryana, Dixit (2007) observed that the yield from green house crops was several times more than the yield obtained from outdoor cultivation depending upon the cropping system and the degree of environmental control. The germination percentage was found 10-20 per cent more in green house as compared to open field. As green house cultivation is capital intensive, the initial heavy financial investment must be compensated by additional crop yield and export oriented crops. The study revealed that the green house cultivation showed superior yield and yield attributing characters as compared to open field condition.

Singh and Sirohi (2008) reported that protected cultivation of vegetables offers distinct advantages of quality, productivity and favourable market price to the growers. Vegetable growers can substantially increase their income by protected cultivation of vegetables in off-season through price advantage. Walk-in tunnels are found to be suitable and effective to raise off-season nursery and off-season vegetable cultivation due to their low initial cost in the Northern plains of India. Low cost green houses can be used for high quality vegetable cultivation for long duration (6-10 months) mainly in peri-urban areas of the country to fetch commensurate prices of produces. Polytrenches have proved extremely useful for growing vegetables under cold desert condition in upper reaches of Himalayas in the country.

Among the various growing environments tried, performance of rose varieties under polyhouse was most satisfactory with improved growth and floral characters including yield of flowers, increase in plant height, number of bottom breaks and plant spread as compared to open field condition (Mohanty *et al.,* 2008).

Kumar and Arumugam (2010) reported that the weather parameters (temperature, relative humidity, light) inside the polyhouse had significant positive influence on the growth and yield of different vegetables in comparison with open field in their study at TNAU, Madurai.

Parvej *et al.* (2010) of Bangladesh Agricultural University, Mymensingh in an experiment on the phenological development and production potentials of tomato under polyhouse climate reported that the microclimate inside polyhouse favoured the growth and development of tomato plants as compared to open field conditions. Early flowering, fruit setting and fruit maturity was observed in polyhouse plants compared to open field. The fruit yield obtained from polyhouse was also higher (81 t/ha) against that from the open field (57 t/ha).

While studying the performance of sweet pepper (*Capsicum annum*) varieties and economics under protected and open field conditions in Uttarakhand, Singh *et al.* (2011) reported that maximum crop duration (270 days) along with maximum fruit diameter (6.91 cm), maximum no. of fruits/ plant (47), highest individual fruit weight (62.17 g), average fruits weight (2.91 kg/plant) and yield (17.48 kg/m2) was recorded in sweet pepper under polyhouse conditions as compared to poly-tunnel, plastic- mulching treatments and open field condition.

The study of insect-pest incidence to minimize insecticide application for quality production of high value horticultural crops carried out at CPCT, IARI, New Delhi by Singh *et al.* (2012) revealed that the minimum incidence of insect pests, plant mortality and spraying of insecticides were observed under polyhouse condition as compared to open field conditions. The unmarketable fruits were almost nil under polyhouse condition. It is concluded that cultivation under polyhouse is thus a better technique of Integrated Pest Management.

While discussing on 'greenhouse farming; the future of Kerala', Rajeevan (2012) states that in a tropical zone like Kerala, the protected cultivation structures are having a wide range of purposes as the climatic conditions are diverse .He also put forth three thrust areas of research in the context of greenhouse farming in Kerala that included standardization of location specific greenhouse systems, performance evaluation of crops in greenhouses, development of organic practices under greenhouse cultivation.

Manohar (2012) suggested that greenhouse structures erected should be location specific, and the design should depend upon the type of construction materials, control systems provided and the purpose for which it is to be used. He also reports that GI pipe frame work is ideal as compared to low cost wooden structures considering the longevity and cost of maintenance. Multi span greenhouse of minimum 1080 m^2 area oriented in North-South direction is found desirable for commercial production of horticultural crops.

Studies conducted at Thrissur, Kerala to standardize the structural design of greenhouse suited to Kerala conditions by Suseela and Devadas (2012) summarize that gable shaped greenhouse oriented in North-South direction with effective side ventilation of not less than 30 per cent combined with foggers at a spacing of 1.25m x 1.25m to 2m x 2m is considered to be the best model for Kerala conditions.

Sabir and Singh (2013) reported that greenhouse vegetable crops grown the world over are vulnerable to various diseases and pest attacks as the environment inside is conducive for their rapid multiplication. The amount of losses due to virus alone can vary from five per cent to 90 per cent.

In an experiment on the effect of growing conditions on seed yield and quality of cucumber (*Cucumis stivus*) hybrid, carried out at CPCT, IARI, New Delhi, Kaddi *et al.* (2014) observed that the seed quality attributes, viz. germination percentage, seedling length, seedling dry weight, vigour index I and II and seed moisture content immediately after harvest were significantly superior in naturally ventilated polyhouse and insect proof net house in comparison to open field conditions.

Kishore *et al.* (2014) in a study on sequential vegetable production under protected condition observed that yield and production efficiency in open field condition were approximately half than that of protected condition. The higher yield in polyhouse was attributed to the prevalence of congenial microclimate in terms of temperature and relative humidity inside polyhouses.

In a study on advances in protected cultivation of vegetables in Kerala, Kutty *et al.* (2014) suggest that rain shelters are effective for year-round production of vegetables in homesteads of Kerala; while naturally ventilated polyhouses are suitable for commercial production of high value vegetables In the state.

Spehia *et al.* (2014) recommend that V trellis with four stems at 40 cm×40 cm spacing is optimum for more income per rupee invested for greenhouse cultivation of coloured capsicum based on their studies carried out at Y.S Parmer University of Horticulture and Forestry, Himachal Pradesh. Although, fruit weight and yield/plant were higher in wider spacing treatment, yield per square meter was significantly higher in close spacing.

2.4 Problems and prospects of polyhouse/ protected cultivation

Singh and Vishist (1999) in the study entitled 'An analysis of production and marketing system of vegetable in Lambagaon block of district Kangra (Himachal Pradesh)' made an attempt to examine the input output relationship, relative profitability and the existing marketing system of major vegetable crops. Results revealed that tomato was the most profitable crop in *kharif* season and cauliflower in *rabi* season. It further showed that producers' share in terms of consumers' rupee was very low due to market intermediaries. It was found that major hurdles in the production of vegetables were lack of technical know-how and natural calamities.

Kumar and Singh (2002) while discussing the problems in vegetable production in Bharatpur district of Rajasthan reported that the vegetable growers face problems such as non-availability of inputs at the right time, poor and low quality of inputs, non-availability planting materials of desired varieties in the market, high cost of inputs, lack of knowledge about the use of inputs and non-availability of subsidy. Extensive demonstrations of improved and high yielding varieties of vegetable crops timely supply of crucial inputs at reasonable price and in adequate quantity should be ensured to sustain vegetable production on a profitable basis.

A study on problems and prospects of vegetable production under protected conditions in North Eastern Himalayan region by Sanwal *et al.* (2004) reported that high cost and non-availability of various components were the two major constraints in polyhouse cultivation in NEH regions. Development of low cost technology for construction, raising early crops and vegetable nursery in protected structures in temperate areas were identified as the potential prospects.

Pathare *et al.* (2005) while studying the status of polyhouses in Akola and Washim districts of Maharashtra observed that due to lack of technical knowledge and consultation with extension agencies the polyhouses erected were not as per the design and most of the polyhouses were not working properly. Faulty construction, non availability of electricity, lack of ventilation and tearing of UV stabilized sheet were identified as major problems. Cost reduction using locally available materials for construction, employment generation rural youth were the major prospects of the technology.

Thyagarajan and Prabu (2005) in their study reported that the tomato growers of Tamil Nadu faced the problems such as wide price fluctuations, lack of knowledge to identify pests and diseases, high cost of labour, inadequate water supply, non-availability of credit, exploitation by the middlemen by charging heavy rate of commission and brokerage, lack of adequate transport and market facilities and lack of storage facilities at the village level in the descending order. They suggested fixing a minimum economic price for tomato throughout the entire season, arranging intensive training programmes for tomato growers especially covering identification of pests and diseases, scientific storage as the measures to resolve these problems. Arranging adequate credit facilities and strengthening the existing rural marketing infrastructure including cold storage would help to overcome the major constraints in production and thereby increase the income of tomato growers.

2.5 Adoption of protected cultivation

While studying the extent of adoption of precision agriculture technologies in India, Mondal and Basu (2008) reported that the adoption of precision agriculture in

India is likely to follow the classical 'S' curve pattern. Attitudes of confidence toward using the precision agriculture technologies, perceptions of net benefit, farm size and farmer educational levels would positively influence the intention of farmers to adopt precision agriculture technologies.

The results of the study conducted at Tamil Nadu by Maheswary et al. (2008) on precision farming technologies in resource poor areas showed that the lack of finance and credit facilities were the most important reasons for non-adoption of precision farming followed by lack of knowledge about precision farming technologies and labour scarcity. The financial impact of adoption showed that farm-size, extension agency contact and non-farm income have significant influence on the net return in tomato. Increasing farm size, extension agency contact and non-farm income by one unit will increase the net return by Rs. 1293/ha, Rs. 8242/ha and Rs. 1129/ha, respectively in tomato. In case of brinjal the farming experience and nonfarm income posses a positive influence on the net income in brinjal cultivation. Increasing farming experience, non-farm income by one unit will enhance net return by Rs. 1542/ha, and Rs. 1680/ha, respectively in brinjal.

Kutty *et al.* (2014) while studying the advances in protected cultivation of vegetables in Kerala point out the high initial investment, lack of technical knowhow on scientific management of polyhoues crops and lack of knowledge on the market for the produce as the major challenges faced by polyhouse farmers of Kerala.

The review of literature clearly indicates that evaluation of the viability and feasibility of polyhouse technology has been largely location specific and as such the results of the studies conducted in one area cannot be extrapolated. A wide gap could be observed in the literature regarding systematic evaluation on the performance of the crops under polyhouse/ protected cultivation on a commercial scale in Kerala. The present study is an attempt to overcome the lacuna.

Methodology

3. METHODOLOGY

The location of the study, design of the study undertaken and methods of analysis are discussed in this chapter. The details are covered under the major headings - location and agro-climatic features of the study area, the sampling design, the method of collection of data and tools of empirical analysis.

3.1 Location of the study

As per the agro-climatic classification, Kerala is classified into five zones; South, central, North, high range and problem zone. The statistics on the number of polyhouses installed indicates that there are more number in the high range and central zones and hence they were fixed as the location of the study.

Thrissur, Ernakulam and Palakkad districts representing the central zone and Wayanad and Idukki districts representing the high range zone were chosen for the detailed study. A description of the land utilization and cropping pattern of the selected districts are given below.

3.1a. Thrissur

Thrissur known as the cultural capital of Kerala is located in the central part of the state in the Northern latitude between 10^0 10' and 10^0 46' and Eastern longitude between 75^0 57' and 76^0 54'. The district shares its boundaries on the North with Malappuram and Palakkad districts, South with Idukki and Ernakulam districts, East with Palakkad and Coimbatore district of Tamil Nadu and West with Arabian Sea. The total geographical area of Thrissur is 3032 sq. km.

The district features a tropical climate. Summer last from March to May followed by the South-West monsoon from June to September. The average annual rainfall of the district is 3100 mm. On an average there are 124 rainy days in a year.

The temperature of the district varies from 33^0 C to 22.5^0 C. Major soil types observed are laterite soil, brown hydromorphic soil, hydromorphic saline soil, coastal alluvium, riverine alluvium and forest loamy soil. Land utilization pattern of the district is given in Table 3.1.

3.1b. Ernakulam

Ernakulam district, one among the most developed districts of Kerala, is spread over an area of 3068 sq. km. The district lies between 9^0 47' and 10^0 18' North latitude and 76^0 9' and 77^0 6' East longitude. It is bounded on the West by Arabian Sea, South by Kottayam and Alappuzha districts, East by Idukki district and on the North by Thrissur district.

The district experiences heavy rainfall during South-West monsoon followed by North-East monsoon. During other months the rainfall is considerably less. March, April and May are the hottest months. December to February are the coldest months. The district receives on an average 3359 mm of rainfall annually. The temperature ranges between 31.4^0 C to 23^0 C. The predominant soil types are laterite soil, brown hydromorphic soil, hydromorphic saline soil, coastal alluvium and riverine alluvium. Land utilization pattern of the district is given in Table 3.1.

3.1c. Palakkad

Palakkad, another central zone districts selected for this study is known as the 'rice bowl of Kerala'; which contributes to a major share (42 %) in the paddy production of the state. The total geographical area of the district is 4475 sq. km. The district is located in the Northern latitude between 100^0 46' and 100^0 59' and in the Eastern longitude 76^0 28' and 76^0 39'. Malappuram, Thrissur and Coimbatore districts of Tamil Nadu are the neighboring districts of Palakkad.

Palakkad and Chittur area of the districts show a comparatively dry climate. Rest of the districts experience a humid climate with very hot seasons extending from March to June. The average annual rainfall of the district is 1831.3 mm. The South-West monsoon contributes major share of the annual rainfall. During December to May, practically no rain is received in the district. The mean temperature varies from 20^0 C to 45^0 C. Prominent soil types include laterite soil, virgin forest soil and black soil. Land utilization pattern of the district is given in Table 3.1.

3.1d. Idukki

Idukki is one of the high range districts of Kerala. Idukki district has an area of 4479 sq. km and is the second largest district of Kerala. The district lies between North latitude of 9^0 15' and 10^0 21' and East longitude of 76^0 37' and 77^0 25'. A major portion of the district is covered by dense forests and extensive tea, coffee and cardamom plantations.

The district receives an average rainfall of 3677 mm. The rainfall increases from East to West. The Eastern part of the districts lies in the rain shadow region of the Western Ghats. The major rainfall contribution is from South-West monsoon from June to September. The temperature is more during March to May and is less during January and February. The average temperature ranges from 31.5^0 C to 14^0 C. There are four major soil types observed in the district, *viz* forest loam, laterite soil, brown hydromorphic soil and alluvial soil. About 60 per cent of the district is covered under forest loam. The land utilization pattern of the district is given in Table 3.1.

3.1e. Wayanad

Wayanad, meaning the land of paddy fields is a small hilly district of Kerala with a total geographical area of 2131 sq. km. The district is located in the Northern latitude between 11^0 36' and 11^0 59' and the Eastern longitude between 76^0 45' and 76^0 83'. About 90 per cent of the population relies on agriculture as their livelihood. Though paddy was the prominent crop earlier, the district is now characterized by cultivation of perennial plantation crops and spices.

Wayanad experiences salubrious climate with mean rainfall of 2786 mm per annum. Southern, South-Western and North-Eastern areas of the district receive more than 3000 mm rainfall per annum. The district experiences an average maximum temperature of 23.78^0 C and a minimum temperature of 13.4^0 C. Laterite soil, brown hydromorphic soil, forest loam and riverine alluvium are the prominent soil types observed in Wayanad district. Land utilization pattern of the district is given in Table 3.1:

Table 3.1. Land utilization pattern of sample districts

Sl. No.	Particulars (Ha)	Thrissur	Ernakulam	Palakkad	Wayanad	Idukki
1.	Total geographical area	302919 (100)	305826 (100)	447584 (100)	212966 (100)	436328 (100)
2.	Forest	103619 (34.01)	70617 (23.09)	136257 (30.44)	78787 (36.99)	198413 (45.21)
3.	Land put to non-agricultural use	37613 (12.21)	40875 (13.36)	45231 (10.10)	11295 (5.30)	12700 (2.9)
4.	Barren and uncultivable land	259 (0.08)	578 (0.18)	1795 (0.40)	71 (0.03)	1833 (0.42)
6.	Land under miscellaneous tree crops	191 (0.06)	121 (0.039)	698 (0.15)	35 (0.01)	248 (0.05)
7.	Cultivable waste	8279 (2.73)	11071 (3.62)	23794 (5.31)	963 (0.45)	2321 (0.53)
8.	Fallow other than current fallow	8256 (2.72)	10350 (3.38)	14152 (3.16)	589 (0.27)	1220 (0.27)
9.	Current fallow	9515 (3.14)	9585 (3.13)	12746 (2.84)	2106 (0.98)	1647 (0.37)
11.	Still water	6328 (2.08)	10410 (3.40)	15340 (3.42)	3904 (1.83)	10480 (2.4)
13.	Social forestry	147 (0.04)	105 (0.03)	379 (0.08)	59 (0.02)	1355 (0.31)
14.	Net area sown	128385 (42.08)	151786 (49.63)	197192 (44.04)	115144 (54.06)	206110 (47.23)
15.	Area sown more than once	49233	13371	104520	59046	57061
16.	Total cropped area	177618 (58.14)	165157 (54.00)	301712 (67.40)	174190 (81.79)	263171 (60.31)

(Figures in paranthesis indicate per cent to total cropped area)
(Source: GOK, 2015)

3.1.2 Cropping pattern

The cropping pattern of the sample districts are shown in Table 3.2. Palakkad with an area of 82896 Ha is the largest paddy producing district of Kerala. In terms of vegetable production also Palakkad with an area of 7173 Ha occupies the first position. Palakkad is also the largest producer of fresh fruits in the state with jack and mango being the major fruit crops cultivated. Thrissur is the third largest coconut producing district with 87177 Ha of area. Thirty six per cent of total cropped area is under rubber in Ernakulam district. The predominent crop cultivated is coffee in the district of Wayanad with an area of 67364 Ha. Idukki has its major share of cultivated land under spices and condiments (31.51 % of total cropped area).

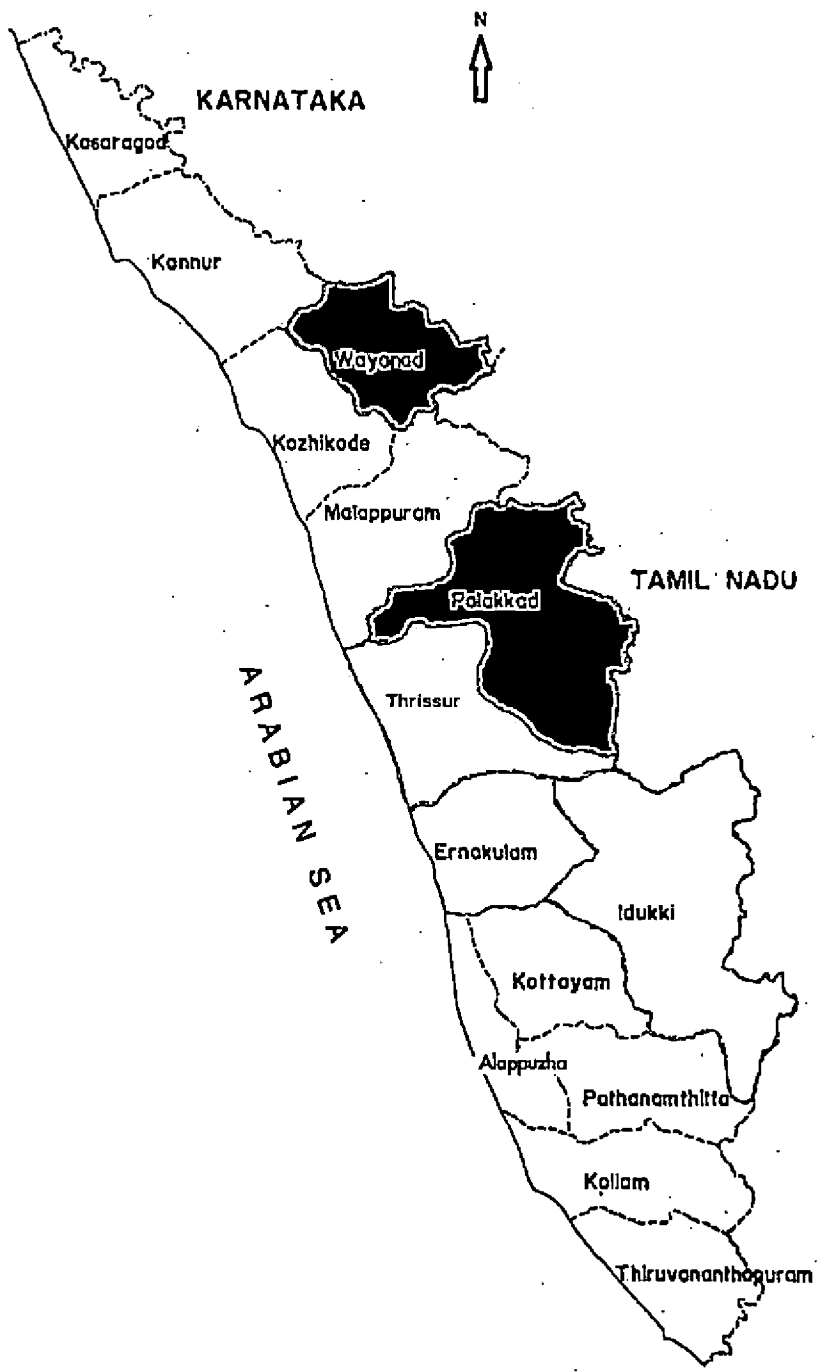
Table 3.2. Cropping pattern of sample districts

Sl. No	Crop	Area (Ha)					
		Thrissur	Ernakulam	Palakkad	Idukki	Wayanad	State total
1.	Paddy	22274 (13.21)	4052 (2.02)	82896 (27.03)	661 (0.25)	11481 (7.01)	199611
2.	Coconut	87177 (49.45)	44582 (27.14)	61016 (20.70)	16518 (6.01)	11725 (7.14)	808647
3.	Fruits	23763 (13.36)	26196 (16.78)	50735 (17.51)	31377 (12.00)	28230 (16.08)	368854
4.	Rubber	15550 (9.12)	59740 (36.01)	37675 (12.14)	40395 (15.01)	10730 (6.04)	548225
5.	Spices & condiments	16607 (9.02)	13692 (8.04)	21250 (7.84)	82363 (31.51)	28249 (16.19)	266026
6.	Vegetables	3109 (2.21)	2567 (2.41)	7173 (2.47)	5535 (2.71)	1397 (0.84)	41262
7.	Tea	530 (0.29)	0	831 (0.27)	21970 (8.01)	5306 (3.45)	30205
8.	Coffee	0	0	4935 (2.36)	13060 (5.98)	67364 (39.02)	85359
9.	Others	8610 (5.05)	14328 (9.04)	35201 (11.32)	51292 (20.14)	9708 (6.52)	268481
10.	Total cropped area	177618 (100)	165157 (100)	301712 (100)	263171 (100)	174190 (100)	2616670

(Figures in paranthesis indicate per cent to total cropped area)

(Source: GOK, 2015)

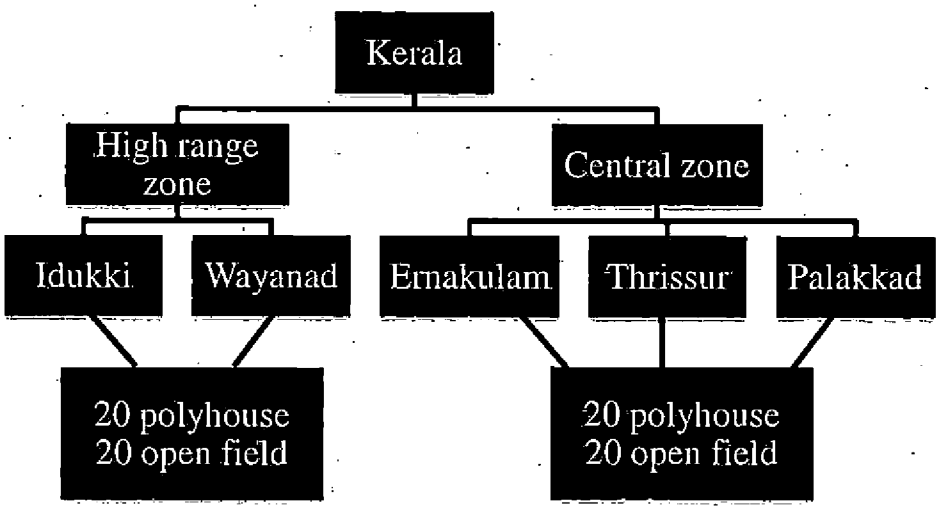
Fig.1. Map of Kerala showing the sample districts



3.2 Sampling procedure

From each zone, 20 farmers cultivating vegetables in polyhouse were selected randomly from the list of total population of polyhouse farmers in each selected district. The numbers of sampling units were fixed in such a way that proportionately higher number of sampling units was selected from districts with higher population of polyhouse farmers. Thus the total number of polyhouse farmers became 40. Similarly, another 20 farmers cultivating vegetables in open field were randomly selected from each zone, such that as far as possible they cultivated the same crops as done in polyhouses in that region. Thus the total sample size added up to 80 (40 vegetable farmers cultivating in polyhouse and 40 farmers in open field).

Fig.2. Sampling design



3.3 Collection of data

Keeping in mind the objectives of the study, a comprehensive interview schedule was prepared. The schedule was pre-tested among a few respondents in the study area before final data collection through pilot surveys conducted in Palakkad

Fig.1. Map of Kerala showing the sample districts

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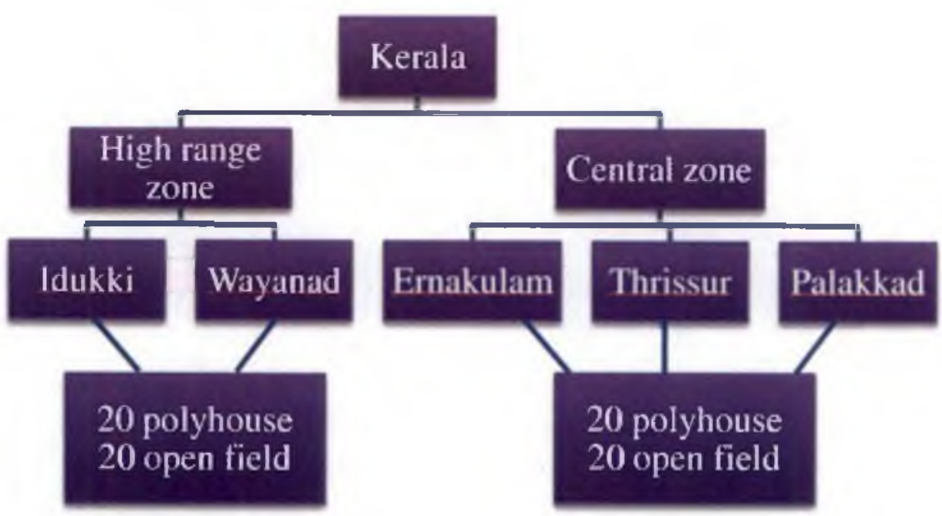

3.3 Collection of data

Keeping in mind the objectives of the study, a comprehensive interview schedule was prepared. The schedule was pre-tested among a few respondents in the study area before final data collection through pilot surveys conducted in Palakkad and Thrissur districts. After pre-testing the interview schedule, the undesirable, ambiguous and difficult to respond questions were made simpler or eliminated. Certain significant questions which sprang up during pilot survey were included in the final interview schedule. Personal interview method using the pre-tested structured interview schedule was adopted for primary data collection. Data on socio economic profile of the farmers, details on various aspects of vegetable cultivation (polyhouse as well as open field), cost of production and returns, problems and prospects of cultivation were collected. The collected data were tabulated and analysed to arrive at results and to draw conclusions. Tabular analysis, percentages and averages were used to describe the socio economic characteristics of the respondents. The economics of production of vegetables in polyhouse, comparison of profitability and resource use efficiency of vegetable cultivation in polyhouse and open field etc. were carried out employing Capital productivity analysis (Pay Back Period, Benefit Cost Ratio, Net Present Value and Internal Rate of Returns), production function analysis (Cobb-Douglas production function), Fishers t test, Cochran – cox t test etc. Kendalls's coefficient of concordance and Logistic regression were used to describe the problems faced by farmers in polyhouse cultivation and to study the factors which influence the decision making in adopting protected cultivation. The concepts used in the study, their measurement and valuation are discussed below.

3.4 Operational definitions and concepts

3.4.1 Protected cultivation

Protected cultivation of crops refers to the creation of favourable environmental conditions around the plants, offsetting or minimizing the detrimental effects of prevailing or expected to prevail abiotic and biotic factors (Singh, 2014). The micro-climate near the plants is controlled with the help of protected structures generally known as greenhouses.

3.4.2 Greenhouse & polyhouse

A greenhouse is a framed or inflated structure covered with a transparent or translucent material where plant environment could be at least partially controlled and which is large enough to permit a person to enter and carry out cultural operations (Chandra, 2014). Polyhouse is a greenhouse with Low Density Polyethylene (LDPE) as the covering (cladding) material.

For the purpose of this study a polyhouse has been operationalized as a closed structure consists of at least the four basic components,

- Frame made of rigid material (GI pipe, wood, bamboo etc.)
- 200 micron thick UV stabilized LDPE polythene sheet as the cladding material
- Climate control system (natural ventilation, forced ventilation, mist, fogger etc.)
- Plant growing medium (soil or artificial media) with needful arrangement for supply of inputs (irrigation, fertigation etc.)

3.4.3 Cost concepts used

The items of costs in the present study have been categorized as fixed cost, annual variable cost and seasonal variable cost as used by Murthy *et al.* (2009) in a study examining the economic viability of production of capsicum and tomato in naturally ventilated polyhouse at Indian Institute of Horticultural Research.

Accordingly, the items of costs are as

- Fixed cost/ Cost of establishment
- Variable costs
  - ➢ Annual variable costs
  - ➢ Seasonal variable cost

3.4.3.1 Fixed cost

Fixed cost includes the cost of establishment of polyhouse. It comprises of cost of GI pipe assembly, aluminium channels, 200 micron UV stabilized polythene sheet, 40 mesh size antivirus and shade nets, drip irrigation and fertigation unit (ventury), fogger or mist and labour charges for erection and fabrication. The costs are estimated on the basis of actual price paid by the farmer.

3.4.3.2 Annual variable cost

Annual variable cost includes the cost of material inputs such as plastic mulch, twines, propping, pandal materials and soil solarization chemicals that are used annually during the production process. The actual price per annum paid by the farmers on these material inputs are taken into account while estimating the annual variable cost.

3.4.3.3 Seasonal variable cost

The costs incurred on inputs that are used for each cropping season are grouped as seasonal variable cost. Seasonal variable cost includes cost of material inputs such as seed, manures, fertilizers and growth promoters, plant protection chemicals and bio control agents, soil ameliorants, packing materials and fuel charges for transportation. Cost of hired human labour, machine labour, post harvest handling and value of family labour incurred for each cropping season are also included as seasonal variable cost.

3.4.3.4 Cost concept for open field vegetable cultivation

The cost concepts followed for polyhouse vegetable cultivation as above have been used in estimating the economics of open field cultivation. Cost of production involves fixed cost, annual variable cost and seasonal variable cost. Fixed cost accounts for the investment made on basic farm implements and machinery. Cost of propping materials and cost of coir or plastic ropes for trailing accounts to the annual variable cost. Cost of material inputs such as seed, manures, fertilizers and growth promoters, plant protection chemicals and bio control agents, soil ameliorants, packing materials and fuel charges for transportation are included as seasonal variable cost. Seasonal variable cost also includes cost of hired human labour, and value of family labour incurred for each cropping season. Family labour and hired labour were treated alike and converted into a common physical unit in terms of man-day equivalent. Eight hours of labour is equivalent to one man day. Both hired and family labour are valued at the prevailing wage rates in the area.

3.5 Tools of analysis

3.5.1 Capital productivity analysis

Capital productivity analysis is the most important tool for evaluating the financial feasibility of enterprises. It brings out the efficiency of capital use in production. As polyhouse involves huge initial investment, it is necessary to take into account the income stream for the whole lifespan of polyhouse. However, since it is difficult to generate the cash flows for the entire lifespan of polyhouse in the absence of observed temporal information on benefits and costs, a few assumptions were made to estimate both the cash inflows and cash out flows for polyhouse cultivation of vegetables.

- The lifespan of the polyhouse is 10 years.
- The income stream of the polyhouse is uniform and constant over its entire life.

The four measures of capital productivity analysis used in this study are:

a) Pay Back Period (PBP)
b) Benefit Cost Ratio (BCR)
c) Net Present Value (NPV)
d) Internal Rate of Return (IRR)

The cost of cultivation and returns obtained over the economic life of polyhouses were used in the computation. Excepting PBP, all others are discounted measures of economic appraisal. For estimating these parameters costs and returns are discounted at 12 per cent rate of interest, being the rate at which medium term and long term credit could be obtained from commercial banks.

3.5.1.1 Pay Back Period (PBP)

PBP is an undiscounted measure of the worth of an endeavor, which measures the efficiency of cultivation by indicating the period within which the returns offset the investment. PBP has two major draw backs as a measure of investment worth: a) it does not consider earnings after this period and b) it fails to take into consideration difference in the timing of earnings during the period. Given the expected life of the project, the shorter the PBP, the greater is the profitability. The PBP can be assessed by estimating the progressive total of returns and costs. The year at which progressive total of returns exceeds progressive total of costs is considered as the PBP.

3.5.1.2 Benefit Cost Ratio

The benefit cost ratio indicates the return on a rupee of investment. It is the ratio between the present worth of benefits and that of costs (Gittinger,1984). A project with benefit cost ratio greater than unity is considered viable.

$$BCR = \frac{\sum_{t=1}^{n} \{Bt / (1 + i) t\}}{\sum_{t=1}^{n} \{Ct / (1 + i) t\}}$$

Where, t = 1..........n years

(n = Total no of years of the project)

B_t = Benefits in t^{th} year

C_t = Costs in the t^{th} year

i = Discount rate

3.5.1.3 Net Present Value (NPV)

This is the most straight forwarded discounted cash flow measure of project worth. This is simply the present worth of the net cash flow stream (Gittinger, 1984). In other words it is the difference between present worth of benefits and present worth of costs. The formal selection criteria for the NPV measure of project worth is to accept all projects with a positive net present value when discounted at the opportunity cost of capital.

$$NPV = \frac{\sum_{t=1}^{n} \{Bt - Ct) t\}}{(1 + i)^{t}}$$

Where, t = 1.........n years

(n = Total no. of years of the project)

Other symbols are same as mentioned above.

3.5.1.4 Internal Rate of Reture (IRR)

Another way of using discounted cash flow for measuring the worth of a project is to find that discount rate which just makes the net present value of the cash flow equal to zero. This discount rate is termed the Internal Rate of Return and it represents the average earning power of money used in the project life (Gittinger, 1984). Based on this criterion, a project is considered worth to be accepted if the IRR is above the opportunity cost of capital.

Symbolically, internal rate of return (IRR) is that discount rate 'i' such that,

$$NPV = \frac{\sum_{t=1}^{n} \{Bt - Ct)\, t\}}{(1+i)^t} = 0$$

Where t = 1..........n years

(n = total no. of years of the project)

Other symbols are as mentioned above.

While working out IRR an arbitrary discount rate is assumed and its corresponding NPV is arrived at. This process is continued till NPV becomes negative. Then by interpolation method the exact IRR is found out using the following equation:

$$IRR = (\text{lower discount rate}) + (\text{Difference between two discount rates}) \times \frac{\text{NPV at lower discount rate}}{\text{Absolute difference between NPV at the two discount rates}}$$

3.5.2 Regression analysis

Resource use efficiency of cultivating vegetables in polyhouse and open field was studied employing regression analysis. Multiple linear regression is used when the value of a variable has to be predicted based on the value of two or more other variables. It also allows to determine the overall fit (variance explained) of the model and the relative contribution of each of the predictors to the total variance explained. Multiple linear regression fitting Cobb-Douglas production function was adopted to estimate the resource use efficiency of vegetable production under polyhouse and open field conditions. This model is well known for its computational simplicity that justifies its wide application on production relations (Handerson and Quandt, 1958). A properly estimated production function such as Cobb- Douglas production function could provide a wealth of theoretically appropriate information to guide farmers in their input and output decisions (Biddle, 2010).

The form of Cobb Douglas production function used for both polyhouse and open field vegetable cultivation conditions is as follows.

$$Y = a X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} X_7^{b7} X_8^{b8}$$

Where,

Y = Net returns/m^2 (Rs/m^2)

X_1 = Value of seeds used/m^2 (Rs/m^2)

X_2= Value of hired human labour utilized/m^2 (Rs/m^2)

X_3 = Value of family labour utilized/m^2 (Rs/m^2)

X_4 = Transportation charges incurred/m^2 (Rs/m^2)

X_5 = Quantity of soil ameliorants applied/m^2 (kg/m^2)

X_6 = Quantity of manures applied/m^2 (kg/m^2)

X_7 = Quantity of fertilizers applied/m^2 (kg/m^2)

X_8 = Quantity of plant protection chemicals and bio control agents applied/m^2 (g/m^2)

b_i = Regression coefficients of i^{th} input

The Cobb-Douglas production function was converted into log linear form and the parameters (coefficients) were estimated by employing Ordinary Least Square (OLS) technique.

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + b_8 \ln X_8 + u \ln e$$

Where, u = Random error term

3.5.2.1 Returns to scale

In a Cobb-Douglas production function, the sum of variables ($\beta 2 + \beta 3$) gives information about the returns to scale, that is, the response of output to a proportionate change in the inputs. If this sum is 1, then there are constant returns to scale. If the sum is less than 1, there are decreasing returns to scale and if it is greater than 1, there are increasing returns to scale (Gujarati *et al.*, 2004).

3.5.3 Estimation of efficiency ratio of vegetable cultivation in polyhouse and open field

Economic efficiency combines both the technical and allocative efficiency. The efficiency of resource use is also determined by the ratio of Marginal Value Product (MVP) of a particular input and the Marginal Factor Cost (MFC) of that input. The estimated coefficients of significant independent variables in the regression equation are used to compute the marginal value products (MVP) and the resource-use efficiency (r) is worked out using the following equation:

$r = MVP/MFC$

Where,

r = Efficiency ratio

MVP = Marginal value product of variable inputs

MFC = Marginal factor cost (price per unit inputs)

$MVP_i = \beta_i (Y/X_i) \times P_y$

Where,

MVP_i = Marginal value product of the i^{th} input,

Y = Geometric mean of the value of output,

X_i = Geometric mean of the i^{th} input,

β_i = Estimated co-efficient (or) elasticity of the i^{th} input

P_y = Price of output.

(Parasar et. al., 2016)

MFC of each input is obtained from the data collected on the unit market prices of the various. The decision rule for the efficiency analysis is if:

r = 1; resource is been used efficiently

r >1; resource is underutilized and increased utilization will increase output.

r <1; resource is over utilized and reduction in its usage would lead to maximization of profit.

3.5.4 Logistic regression

The factors which influence the decision making in adoption of protected cultivation were studied using logistic regression. Logistic regression, or logit regression, or logit model is a regression model where the dependent variable is categorical. A binary logistic regression is employed in which the two sample respondent groups are adopters represented by polyhouse farmers (1) and non adopters represented by open field vegetable farmers (0). The logistic regression predicts the odds of being a case based on the values of predictors or independent variables. The odds are defined as the probability that a particular outcome is a case (or success) divided by the probability that it is a non-case (or failure).

The variables used for the analysis are: age, education level, occupation status, years of experience in agriculture, family income and land holding size.

The binary logistic regression analysis has been carried out employing the SPSS with several independent variables and a dichotomous categorical variable. With probability as:

$$P(Y) = \frac{e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_n x_n}}{1 + e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_n x_n}}$$

Where,

P = probability of Y occurring

e = natural logarithm base

b_0= interception at y-axis

b_1= line gradient

b_n= regression coefficient of X_n

X_1= predictor variable

3.5.5 Fisher's't' test ('t' test for independent samples)

The test is used to know whether the two random samples are drawn from the same population or two different populations with equal variance. In other words, it is a test of equality of population means based on two independent (random) samples when population variances are equal. The following assumptions are inherent in the use of the test:

- Samples are random and independent
- Samples are drawn from a normal population
- Sample variances are homogeneous (population variances are equal) and unknown

To test the validity of the test assumptions, 'F' test is used. Fisher's't' test is applicable if 'F' test is not significant. In case 'F' test shows unequal varience, one has to apply either Fisher- Bahren'd' test or Cochran - Cox 't' test. The test criterion for Fisher's't' test is given by:

$$t = \frac{\bar{x}1 - \bar{x}2}{s\sqrt{\left(\frac{1}{n1}\right)+\left(\frac{1}{n2}\right)}}$$

Where, $S^2 = (n_1 - 1) S_1^2 + (n_2 - 1) S_2^2 / (n_1 + n_2 - 2)$

$\bar{x}_1$ = First sample mean

$\bar{x}_2$ = Second sample mean

n_1 = First sample size

n_2 = Second sample size

The critical ratio defined by the above formula follows the't' distribution with degrees of freedom equal to $n_1 + n_2 - 2$. A significant 't' implies the population means are unequal.

3.5.6 Cochran – Cox't' test

The test is used to test the equality of population means based on small samples when sample variances are heterogeneous. The test criterion is given by,

$t = |\bar{x}_1 - \bar{x}_2| / \sqrt{(w_1 + w_2)}$

Where, $w_1 = S_1^2 / n_1$

$w_2 = S_2^2 / n_2$

t' follows an approximate 't' distribution. The critical values of the test criterion is given by,

$t' = (t_1 w_1 + t_2 w_2) / (w_1 + w_2)$

Where, $t_1 = t_{(n1-1)}$ (α)

$t_2 = t_{(n2-1)}$ (α)

t_1 and t_2 are tabular values of 't' corresponding to $(n_1 - 1)$ and $(n_2 - 1)$degrees of freedom and at α % level of significance. If $t \geq t'$ the null hypothesis of equal population means is rejected.

3.5.7 Kendall's coefficient of concordance

Kendal's coefficient of concordance is used to find out the overall agreement among the farmers in listing out the advantages and disadvantages of polyhouse cultivation in the present study. Coefficient of concordance is a generalization of the rank correlation coefficients to the case of k (>2) attributes. It indicates the degree of agreement between k sets of rankings. To compute Kendall's coefficient of concordance (w), the sum of ranks R_j for each character is worked out, then the mean of R_j is found out. Then each of the R_j may be expressed as a deviation from the mean value. Finally, S, the sum of squares of these deviations is found out and the value of 'w' is computed as:

$$w = 12\, S / K^2 (n^3 - n)$$

$$S = \sum \left[Rj - \sum \left(\frac{Rj}{n} \right) \right]^2$$

Where, K = number of sets of rankings (judges)

n = number of objects ranked

Significance of w is tested using the χ^2 test given by,

$\chi^2 = K (n - 1)w$, which follows χ^2 with n-1 degrees of freedom.

Results and Discussion

4. RESULTS & DISCUSSION

The salient findings of the study based on the information collected and subjecting the data to statistical analysis are presented under five major heads. The first session deals with socio economic profile of farmers engaged in polyhouse and open field cultivation. General information on the production of vegetables in polyhouses is presented in the second session. In the third session, economic analysis including resource use efficiency and capital productivity analysis are dealt with. Decision making in adoption of polyhouse cultivation is discussed in the fourth session. The last session deals with the constraints faced by farmers in polyhouse and open field vegetable cultivation.

4.1. Socio economic profile of sample farmers
4.2. Production of vegetables under polyhouses
4.3. Economic analysis of vegetable cultivation
4.4. Decision making in polyhouse cultivation
4.5. Constraints faced by farmers in polyhouse cultivation

4.1 Socio economic profile of sample farmers

A narrative of the general socio-economic condition of the sample is unavoidable for any study on economics. An understanding of the sample based on their age, gender, educational occupational and income status, etc. would help in easy comprehension of results and interpreting it in a better way. A comparison on the socio-economic profile of polyhouse and open field vegetable farmers of the study area is attempted here.

4.1.1 Gender wise distribution of respondents

The distribution of male and female farmers engaged in polyhouse and open field cultivation of vegetables is presented in table 4.1. In both the categories male farmers are prominent (> 80 %). Involvement of female farmers is slightly higher in polyhouse vegetable cultivation with 17.5 per cent out of the total polyhouse farmers than the open field cultivation with a female participation of 15 per cent out of the total.

Table 4.1. Distribution of males and females engaged in polyhouse and open field cultivation of vegetables

Zone	District	Polyhouse farmers (numbers)		Open field farmers (numbers)	
		Male	Female	Male	Female
Central zone	Ernakulam	7	1	6	2
	Thrissur	5	2	5	2
	Palakkad	4	1	5	0
High range zone	Idukki	4	2	5	1
	Wayanad	13	1	13	1
Total		33 (82.5)	7 (17.5)	34 (85)	6 (15)

(Figures in parenthesis indicate per cent to total)

Polyhouse farmers in Idukki district have the highest proportion of females; out of the six farmers from the district two were female (33.33%). Next position is occupied by Thrissur district, where the proportionate female participation both in polyhouse and open field cultivation are equal, ie. out of the seven farmers randomly selected from each category two from both are females. Proportionately least number of female farmers are found in Wayanad district. Out of the 14 polyhouse farmers selected, only one female is there. The situation is right the same with open field cultivation. In case of open field vegetable cultivation, in Palakkad, out of the five sample farmers none are females. When the central and high range zones are considered together, more female participation is observed in polyhouse cultivation than open field cultivation. All of the female polyhouse farmers have individually owned polyhouses except for a single polyhouse at Thrissur maintained by a woman SHG.

The ease of carrying out farming operations, less dependence on hired labour, problems in land availability etc. might have attracted female farmers more towards polyhouse cultivation than open field vegetable cultivation.

4.1.2 Age wise distribution of respondents

Majority of open field and polyhouse sample farmers fell in the age group between 49-59 years. On a comparison, both polyhouse and open field categories has maximum number of farmers in the 49-59 years age group; in tune with the general trend. Out of the total 40 polyhouse farmers, nearly 24 per cent are of the age between 49-59 years (23.75 %). Number of farmers belonging to the age group 29-39 years is found higher (20 %) among polyhouse farmers than open field farmers; and, it is the category where the least number of farmers are included among the total open field farmers (15 %), only 17.5 per cent of the polyhouse farmers belong to the age group of 59-69 years.

PLATE 1. Field survey in the study area

Table 4.2. Distribution of farmers according to age groups

Age group (years)	Polyhouse			Open field cultivation		
	Central zone	High range zone	Total	Central zone	High range zone	Total
29-39	3 (15)	5 (25)	8 (20)	3 (15)	3 (15)	6 (17.5)
39-49	6 (30)	2 (10)	8 (20)	5 (25)	6 (30)	11 (23.75)
49-59	8 (40)	9 (45)	17 (42.5)	8 (40)	7 (35)	15 (40)
59-69	3 (15)	4 (20)	7 (17.5)	4 (20)	4 (20)	8 (18.75)
Total	20 (100)	20 (100)	40 (100)	20 (100)	20 (100)	40 (100)

(Figures in parenthesis indicate per cent to total)

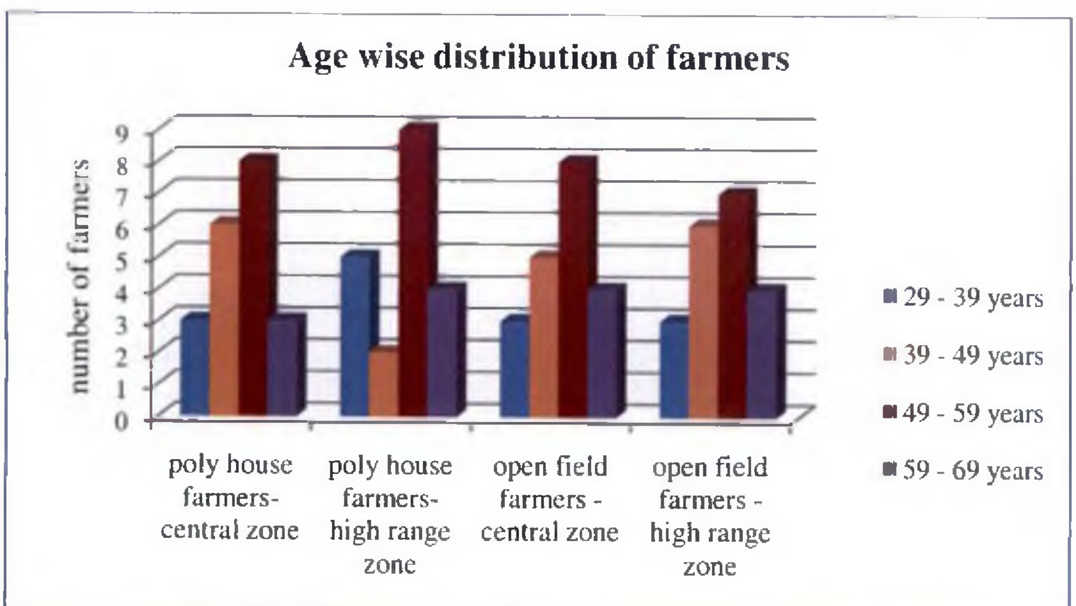

Fig.3. Age wise distribution of polyhouse and open field farmers

The data reveal that in spite of whether open field or polyhouse cultivation, majority of the farmers belong to the age group 49-59 years. This general trend may be attributed to their past experiences and traditional attachment to farming which makes them rely on agriculture as a sole occupation or an activity along with other occupations. Another reason for the increased number of farmers from this age group can be attributed as, 49-59 years is a time period when most of the employed people got retired or relieved from their employment. Most of them might have chosen agriculture as their immediate engagement or income generating activity. The increasing popularity of polyhouse cultivation through media, the curiosity to adopt a new technology, less knowledge and experience in conventional open field cultivation might have motivated them to adopt polyhouse cultivation over conventional open field vegetable cultivation.

Out of the total 80 farmers, the least number of farmers is seen falling in the category of 29-39 years of age. This implies the reluctance of young generation in taking up farming. When the polyhouse and open field statistics are viewed separately, it is still lower for open field cultivation (15 %). Whereas, farmers from the age group 29-39 years stand in the second position in case of polyhouse cultivation. It is indicative of the acceptance of polyhouse technology among the young generations over the conventional open field cultivation. The novelty of technology involved, reduced drudgery in farming, increased popularity in media etc. might have attracted the younger generations towards polyhouse cultivation. The risk bearing ability, innovative nature etc. of the youth might have contributed to increased adoption of polyhouse cultivation.

4.1.3 Education level of respondents

Distribution of polyhouse and open field farmers according to education attained (Table 4.3) shows that more than half of the open field farmers are having primary schooling (57.5 %). On the other hand majority of polyhouse farmers are graduates (33 %) and 45 per cent of polyhouse farmers in the high range zone are graduates. Postgraduates are seen only among polyhouse farmers (7.5%) The numbers of farmers having education up to higher secondary level are equal among polyhouse and open field farmers (20 %).

Table 4.3. Distribution of polyhouse and open field farmers based on education

Education level	Polyhouse farmers			Open field farmers		
	Central zone	High range zone	Total	Central zone	High range zone	Total
Up to Secondary level	5 (25)	6 (30)	11 (27.5)	12 (60)	11 (55)	23 (57.5)
Secondary – Higher secondary level	7 (35)	1 (5)	8 (20)	3 (15)	5 (25)	8 (20)
Graduate	4 (20)	9 (45)	13 (32.5)	3 (15)	3 (15)	6 (15)
Post graduate	2 (10)	1 (5)	3 (7.5)	0 (0)	0 (0)	0 (0)
Technical	2 (10)	3 (15)	5 (12.5)	2 (10)	1 (5)	3 (7.5)
Total	20 (100)	20 (100)	40 (100)	20 (100)	20 (100)	40 (100)

(Figures in parentheses indicate per cent to total)

The results analysed above points out to a positive relationship between polyhouse farming and educational level of farmers. The educational level of polyhouse and open field farmers indicate that educated people are more attracted towards polyhouse cultivation. Out of the 40 polyhouse farmers surveyed majority are graduates (33 %) whereas it is only 7.5 per cent in case of open field farmers.. The sophisticated technologies, technical skills required, lack of wide know how about polyhouse farming might have inhibited the less educated farmers from adopting polyhouse farming.

Another observation is that 29 out of 40 polyhouse farmers are having higher secondary or above education level, whereas it is only 17 out of the 40 farmers in the case of open field farmers. This also indirectly points out that educated people are reluctant to take up open field vegetable cultivation. The lower social recognition as a farmer, risks associated with farming, unwillingness towards physically challenging works etc. might have been the reasons behind this.

During the study, it was observed that most of the polyhouse farmers had good knowledge about the history of polyhouse farming, science behind the technology, world scenario, problems and prospects. They were eager to gather information on polyhouse technology from different sources. Most of them have travelled extensively to study about the technology. Their higher education level must have certainly helped them in all these.

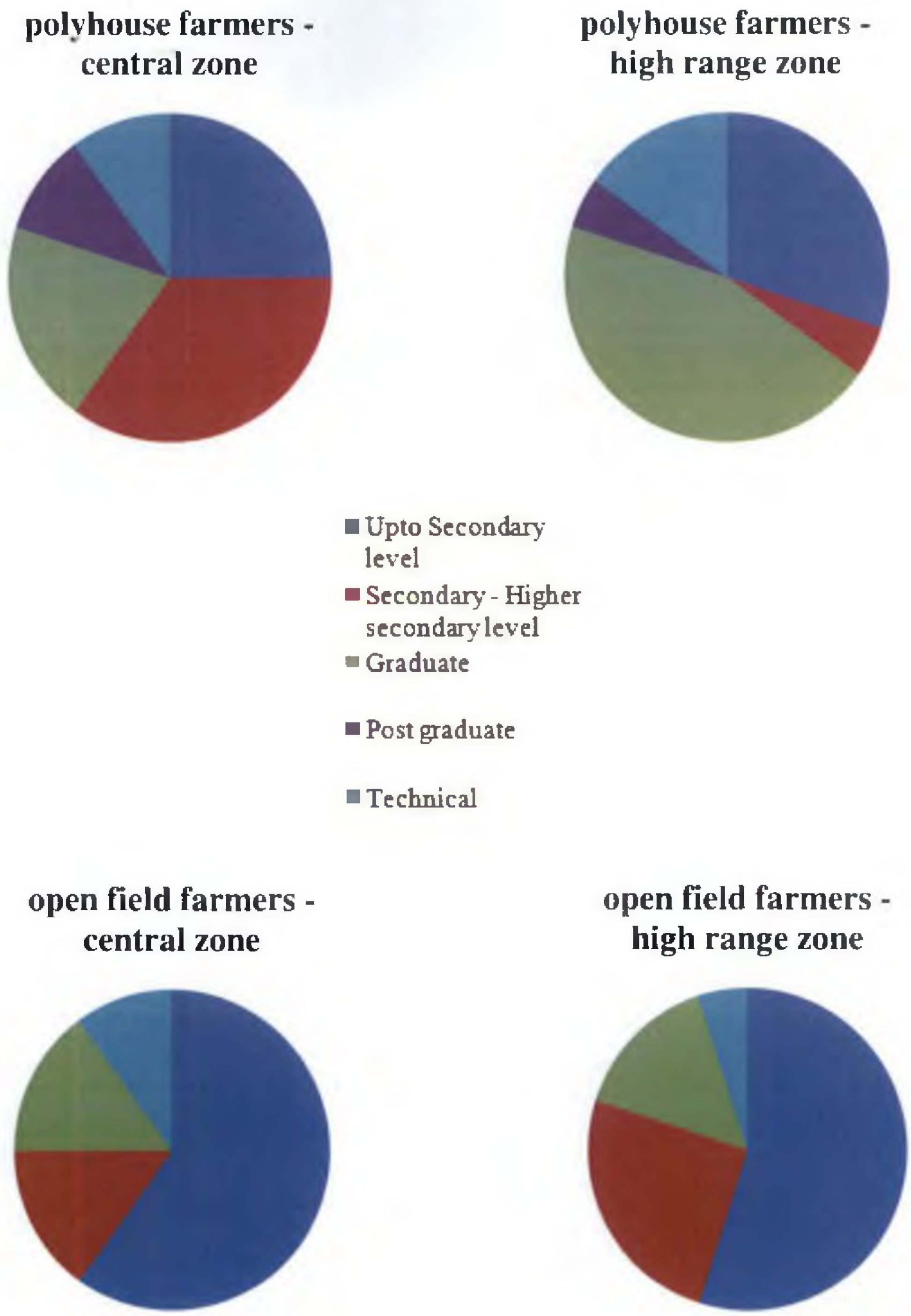

Fig.4. Distribution of polyhouse and open field farmers based on education

4.1.4. Occupational profile of respondents

From the Table 4.4 it could be seen that out of the 20 polyhouse farmers from central zone 11 were having farming as their sole occupation. Two respondents each were government employees, entrepreneurs and home makers. Three out of 20 respondents were engaged in business apart from agriculture. In the total 20 open field farmers from central zone, nine had agriculture as their sole occupation. Four out of 20 respondents were homemakers engaged in agriculture as their part time activity. The rest includes four entrepreneurs and two engaged in small businesses.

Table 4.4. Distribution of respondents based on main occupation

Occupation	Polyhouse farmers		Open field farmers	
	Central zone	High range zone	Central zone	High range zone
Farmer	11	10	9	7
Home maker	2	3	4	2
Business	3	6	2	4
Govt. employee	2	0	0	0
Entrepreneur	2	1	4	5
Others	0	0	1	2
Total	20	20	20	20

Ten out of 20 polyhouse farmers from high range zone had their main occupation as farming. The rest includes six respondents engaged in business, three home makers and one entrepreneur engaged in polyhouse cultivation apart from these occupations. There were only seven farmers who had farming as their sole occupation among the 20 open field farmers in high range zone. Others included five entrepreneurs, four engaged in business, two home makers and two engaged in other private jobs apart from farming.

A comparison between the occupation of respondents before and after the establishment of polyhouse or start of vegetable cultivation has been attempted. It showed that 55 per cent of polyhouse farmers from central zone showed no shift in occupation, but, rest had been engaged in other occupations before getting into polyhouse farming. .

A breakup of previous occupational status of respondents who have presently taken up farming as their main occupation (Fig. 5) revealed that among the nine polyhouse farmers from central zone majority were Non-Resident Indians (NRIs). Two have left business and entered into agriculture. There were one each of home maker, private employee and government employee who turned to full time farming after the establishment of their polyhouses.

Out of the six 'full time polyhouse farmers' from high range zone two were previously NRIs and government employees and one engaged in private sector.

In the case of open field cultivation, the conversion to full time agriculture is negligible. In the central zone, two out of 20 farmers had shifted business and government employment to full time agriculture. Three out of 20 respondents from high range zone who have presently taken up agriculture as their full time occupation previously were NRI, government employee and business person.

From this data it is evident that majority of the people taking up agriculture as a new venture are amongst polyhouse farmers compared to open field farmers. Among the polyhouse farmers, out of the respondents stepping into agriculture after the establishment of polyhouse, the majority were previously NRIs.

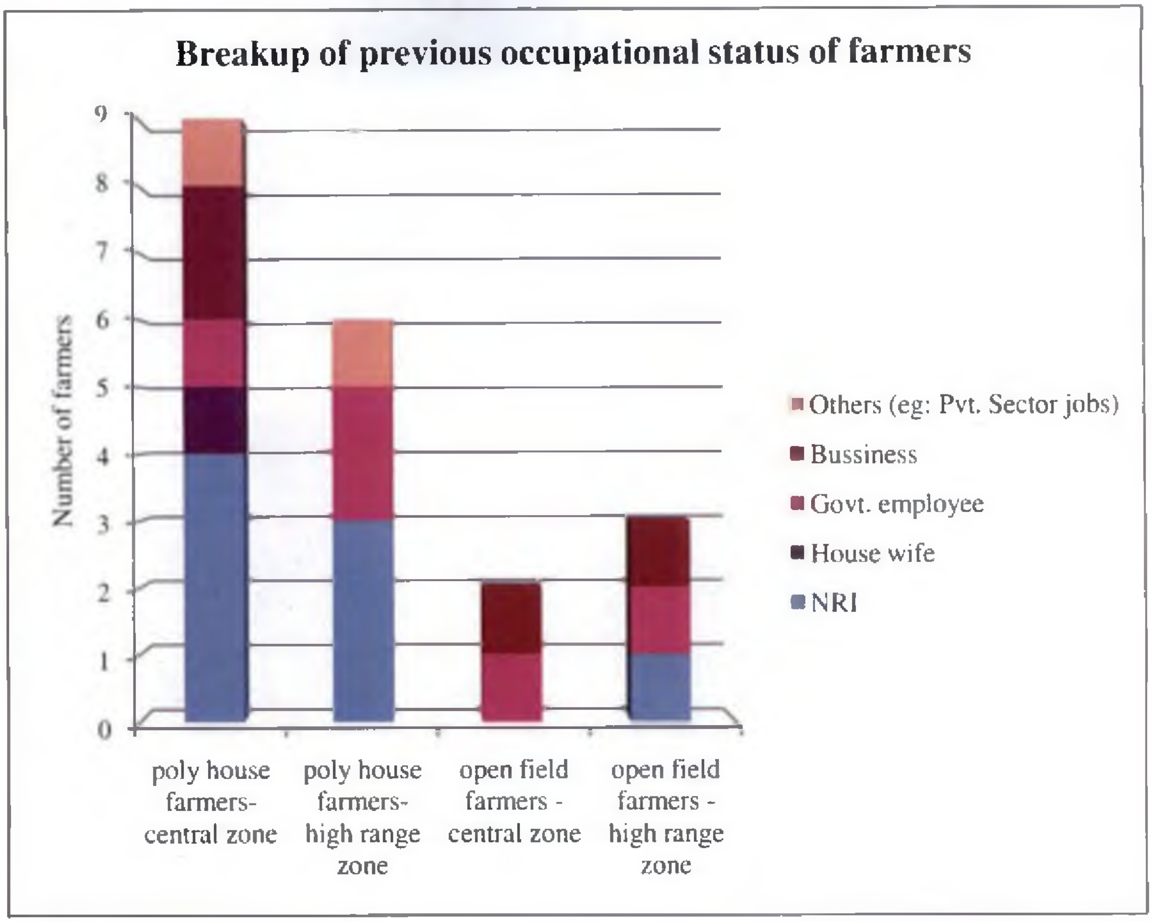

Fig.5. Breakup of previous occupational status of farmers

4.1.5. Years of experience in farming

The distribution of farmers according to years of experience in farming is given in Table 4.5. It is clear that farmers having less than 5 years of experience both in open field and polyhouse cultivation are few in number both in central as well as high range zone.

Table 4.5. Distribution of respondents based on years of experience in farming

Years of experience	Polyhouse farmers			Open field farmers		
	Central zone	High range zone	Total	Central zone	High range zone	Total
Less than 5	3 (15)	1 (5)	4 (10)	1 (5)	0 (0)	1 (2.5)
5-10	4 (20)	5 (25)	9 (22.5)	3 (15)	3 (15)	6 (15)
10-20	5 (25)	4 (20)	9 (22.5)	4 (20)	5 (25)	9 (22.5)
20-25	4 (20)	1 (5)	5 (12.5)	1 (5)	2 (10)	3 (7.5)
More than 25	4 (20)	9 (45)	13 (32.5)	11 (55)	10 (50)	21 (52.5)
Total	20 (100)	20 (100)	40 (100)	20 (100)	20 (100)	40 (100)

(Figures in parentheses indicate per cent to total)

In the central zone, among the polyhouse farmers, majority were having 10-20 years of experience in agriculture. The number of new comers in this field is also noteworthy and it marks a significant 15 per cent of the total polyhouse farmers from central zone. The case of polyhouse farmers from high range zone is slightly different; where the majority of farmers (45 %) are having more than 25 years of experience.

In the case of open field farmers the situation is entirely different from that of polyhouse farmers. Here more than half of the respondents (52.5 %) are having above 25 years of experience in farming. Only 2.5 per cent of the farmers are having less than five years of farming experience, which indirectly point outs that they might be falling in the comparatively younger category of age wise distribution (refer Table 4.2).

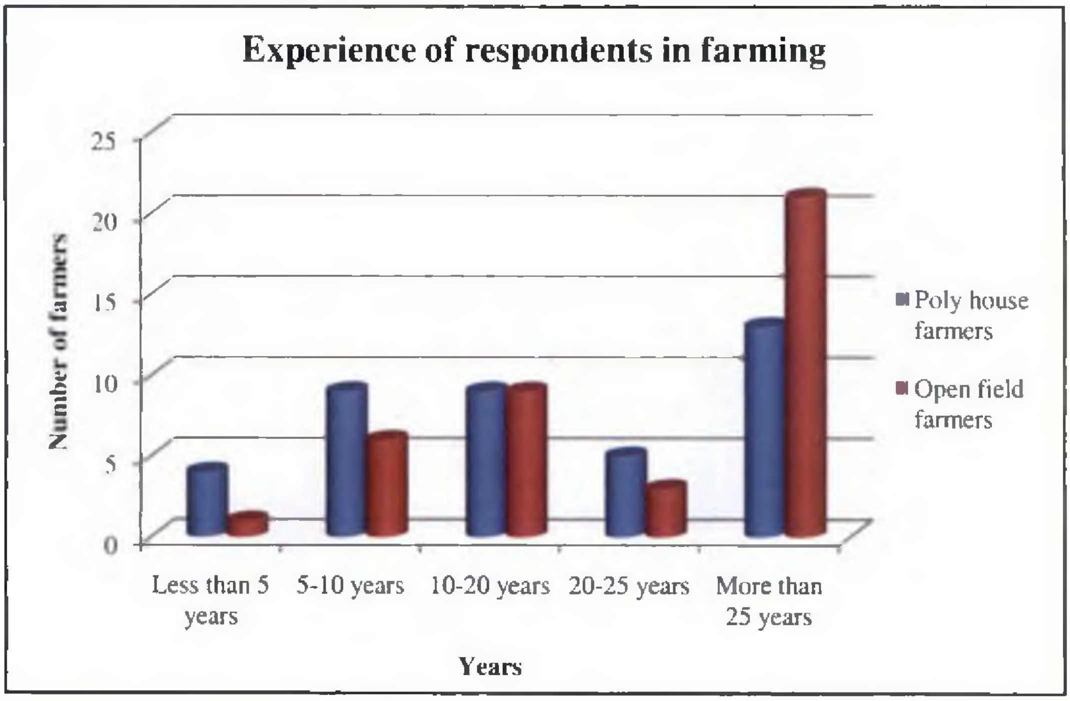

Fig.6. Distribution of respondents based on years of experience in farming

4.1.6. Family income of respondents

Distribution of respondents based on family income given in Table 4.6 indicates that 72.5 per cent of the polyhouse farmers have annual family income above Rs. 1 lakh; out of which 11 respondents fall in the more than Rs. 4 lakh income category. Whereas, 62.5 per cent of the open field farmers have less than Rs. 1 lakh as their annual family income. Five per cent of the open field farmers receive annual income of Rs. 2-4 lakh and only one farmer has annual family income more than Rs. 4 lakh.

Table 4.6. Distribution of respondents based on family income

Annual family income (Rs.)	Polyhouse farmers			Open field farmers		
	Central zone	High range zone	Total	Central zone	High range zone	Total
50,000 - 75,000	2 (10)	0 (0)	2 (5)	3 (15)	5 (25)	8 (20)
75,000 -1,00,000	2 (10)	7 (35)	9 (22.5)	9 (45)	8 (40)	17 (42.5)
1,00,000 - 2,00,000	7 (35)	4 (20)	11 (27.5)	7 (35)	5 (25)	12 (30)
2,00,000 - 4,00,000	5 (25)	2 (10)	7 (17.5)	1 (5)	1 (5)	2 (5)
> 4,00,000	4 (20)	7 (35)	11 (27.5)	0 (0)	1 (5)	1 (2.5)
Total	20 (100)	20 (100)	40 (100)	20 (100)	20 (100)	40 (100)

(Figures in parentheses indicate per cent to total)

Zone wise analysis reveals that among the polyhouse farmers in the central zone, majority (35 %) receives annual family income of Rs. 1-2 lakh. In the high range zone, majority of the farmers are receiving family income of Rs. 75000-1 lakh or above 4 lakh per annum. It was also observed that, there were no polyhouse farmers in the high range zone having family income of less than Rs.75,000 per annum. Among the open field farmers, in both central and high range zone, majority (45 % and 40 % respectively) receive annual family income of Rs. 75000-1 lakh. It was also notable that, hardly a few number of open field farmers were observed in the higher income categories and there were no open field farmers receiving annual income greater than Rs. 4 lakh in central zone.

The data reveals that in terms of annual family income, the polyhouse farmers are relatively richer than open field farmers. For most of the polyhouse farmers, farming is not their major family income source, whereas, for majority of open field farmers, farming is their sole livelihood. It could also be associated that, the higher income level and adoption of polyhouse farming are positively related.

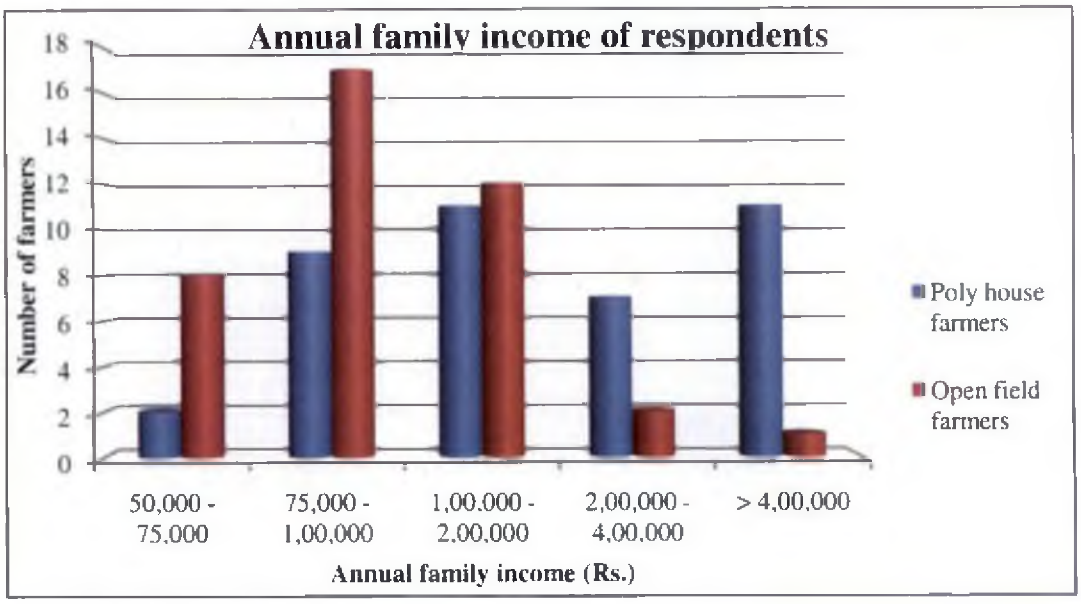

Fig. 7. Family income of respondents

4.1.7 Categorization of farmers according to size of operational holdings

Operational holding of a household is defined as all land - either owned, leased in or otherwise possessed - under physical possession of the household during the major part of a reference period, provided some agricultural production was carried out on any part of the land during the reference period (NSSO, 2006).

Accordingly, the respondents were classified based on the operational holdings they posses into five broad categories (Table 4.7). Majority of polyhouse and open field farmers (42.5 % and 67.5 % respectively) fell in the marginal farmer category. Small farmers contributed 27.5 per cent of polyhouse farmers and 25 per cent of open field farmers. Fifteen per cent of total polyhouse farmers and 2.5 per cent of the open field farmers were categorized as semi-medium. It is also noteworthy that, when 7.5 per cent of polyhouse farmers were grouped as large, there were no large farmers among open field vegetable farmers.

Table 4.7. Distribution of respondents according to size of operational holding (acres)

Category	Number of respondents					
	Polyhouse cultivation			Open field cultivation		
	Central zone	High range zone	Total	Central zone	High range zone	Total
Marginal farmers (≤ 2.5 acres)	9 (45)	8 (40)	17 (42.5)	12 (60)	15 (75)	27 (67.5)
Small farmers (2.6-5 acres)	7 (35)	4 (20)	11 (27.5)	8 (40)	2 (10)	10 (25)
Semi medium farmers (5.1–10 acres)	1 (5)	5 (25)	6 (15)	0 (0)	1 (5)	1 (2.5)
Medium farmers (10.1 – 25 acres)	2 (10)	1 (5)	3 (7.5)	0 (0)	2 (10)	2 (5)
Large farmers (≥ 25.1 acres)	1 (5)	2 (10)	3 (7.5)	0 (0)	0 (0)	0 (0)
Total	20 (100)	20 (100)	40 (100)	20 (100)	20 (100)	40 (100)

(Figures in parentheses indicate per cent to total)

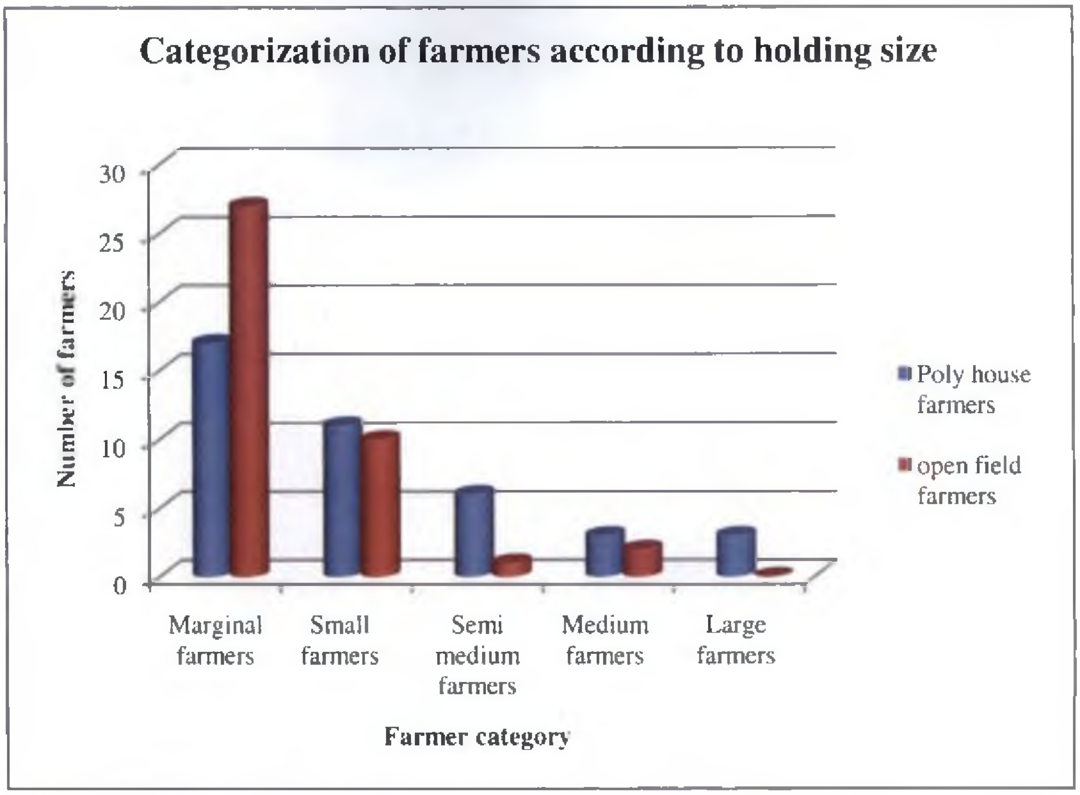

Fig. 8. Categorization of farmers according to land holding size

4.1.8 Borrowing pattern of respondents

Polyhouse cultivation is highly capital intensive and demands high initial investment. The annual family income categorization of the two categories of farmers is a pointer in this regard (Table 4.6). Farmers have to depend heavily on external sources of funding mainly in the form of loans from financial institutions and on subsidies. Table 4.8 presents a comparison of category wise outline of the loans availed by the sample farmers.

Table 4.8. Details of loans availed by the respondents

Polyhouse farmers			Open field farmers		
Category & total no. of farmers	**Number of respondents who availed loans**	**Average amount (Rs.)**	**Category & total no. of farmers**	**Number of respondents who availed loans**	**Average amount (Rs.)**
Marginal farmers n=17	17	346555	Marginal farmers n=27	18	185280
Small farmers n=11	11	222645	Small farmers n=10	3	381250
Semi medium farmers n=6	6	381000	Semi medium farmers n=1	1	87000
Medium farmers n=3	3	375000	Medium farmers n=2	1	200000
Large farmers n=3	3	355000	Large farmers n=0	0	-
Overall average loan availed		320413	Overall average loan availed		207208

It is evident from the table that all the polyhouse farmers surveyed had availed loans; it may be due to the credit - linked nature of the subsidy for polyhouse construction. Only those who are willing to avail bank loan from nationalized banks for polyhouse construction were eligible to receive 75 per cent subsidy on polyhouse construction as per the norms of Government of Kerala. Hence 100 per cent of the polyhouse farmers surveyed had availed loans ranging from Rs. 222645 to Rs. 381000 from Nationalized banks. The overall average loan amount is Rs. 320413 per person among polyhouse farmers. Among the open field farmers only 23 out of the total 40 farmers surveyed had availed loans for agricultural purpose. The overall average loan amount is also lesser compared to that among polyhouse farmers (Rs. 207208 per person).

The analysis of socio-economic profile of polyhouse and open field farmers in the study area indicated that male farmers are prominent in both categories, however a slightly higher proportion of female participation was found among the polyhouse farmers than open field farmers (Table 4.1). Majority of the respondents belonged to the age group between 49 -59 years (Table 4.2). Farmers falling in the age group of 29 – 39 years are found higher among polyhouse farmers. The inquiry into education level of respondents indicated that polyhouse cultivation is taken up more by educated group of farmers than those involved in open field cultivation. More than half of the open field farmers are having primary schooling whereas majority of the polyhouse farmers are graduates among the total respondents (Table 4.3). A comparison of the occupation of respondents before and after the establishment of polyhouse or start of vegetable cultivation amongst the polyhouse and open field farmers revealed that majority of the polyhouse farmers who shifted to polyhouse farming were previously Non– Resident Indians (Fig. 5). When the years of experience in farming is considered, 52.5 per cent of the sample open field farmers are having more than 25 years of experience in agriculture compared to a 32.5 per cent in polyhouse farmers (Table 4.5). The adoption of polyhouse cultivation was found to be positively related with family income. Majority of the open field farmer's fall in the income range of Rs. 75,000 – 1 lakh per annum. Whereas for majority of the polyhouse farmers the annual family income falls in Rs. 1 lakh – 2 lakh category or more than 4 lakh category (Table 4.6). When the farmers were grouped based on the size of operational holdings, marginal farmers were found predominant among both open field and polyhouse farmers. The category of large farmers was only noticed in the group of polyhouse farmers, it marked a significant 7.5 per cent of the total 40 polyhouse farmers. Due to the credit-linked nature of the subsidy on polyhouse construction all of the polyhouse farmers had availed bank loans whereas only 23 out of the total 40 open field farmers depended on institutional credit for cultivation.

4.2. Production of vegetables under polyhouse

The idea of growing plants in an environment - controlled greenhouse goes back to the time of Emperor Tiberius Caesar of Roman Empire era. It consisted of covers made of transparent slate like plates or mica or alabaster. The precursor of modern greenhouses came into picture during the late 15^{th} to early 17^{th} centuries. It began with the use of low portable wooden frames covered with oiled translucent paper to protect the plant environment. The first modern greenhouse, covered with glass was built in late 17^{th} century in Italy to house exotic plants that explorers brought from the tropics. The experiment quickly spread to Holland and England. The use of plastic materials in greenhouse construction was started in 1948 in the USA by Prof. E.M. Emmert of the University of Kentucky, who replaced glass with less expensive polythene as a greenhouse cover. Since then, plastic greenhouse got extended to the five continents and has replaced glass as the cladding material. The twentieth century economic development, especially after the Second World War, led to the construction of polyhouses extensively especially in Mediterranean region, China and Japan.

In Europe, commercial production of vegetables and cut flowers in protected structures started in 19^{th} century. In early 19^{th} century, glasshouses in different designs came up in Europe and Asian countries, mainly in the Netherlands and Japan. A revolution in plastic technology helped in the progress and popularity of protected cultivation. Subsequently, with the development of plastics, several designs of protected structures or greenhouses have evolved.

The lack of water has been the single most important environmental impediment to plant growth and global food production from time immemorial. By far, the most intensive and ancient means of protected cultivation of crops is irrigation. Windbreaks, provides a second means. By irrigation, crop production has been extended to deserts and semi-arid lands that's otherwise would be non-productive (Sylvan *et al.*, 1995). Protected cultivation has now extended far beyond the realms of crop irrigation and water management and has gained different dimensions. It involves the establishment of partial or complete control over plant microclimate so as to alleviate one or more abiotic and biotic stresses for optimum plant growth and production which are achieved in protected cultivation structures such as polyhouses. The protected structures are designed as per the climatic requirements of the crop so that optimum growth and yield could be realized.

4.2.1 Types of polyhouses

The commonly seen polyhouses in India can be classified based on the structure (Quonset type, Gable type, Saw-tooth type etc.), Type of cladding material used (Glass, Fiberglass reinforced plastic, UV stabilized polythene sheet, Silpaulin etc.) and environmental control system adopted (Naturally ventilated, artificially ventilated, fully automated etc.). Naturally ventilated polyhouses are the common type in Kerala. These are simple and medium cost polyhouses having a manually operated cross ventilation system. No heating or cooling devices are provided in naturally ventilated green houses (Singh, 2012).

In the study area, the design type and other technical specifications of polyhouses show no much difference in both the zones (central and high range zones). The predominant type was naturally ventilated saw-tooth type with side and roof ventilation. UV stabilized polythene sheet (LDPE) of 200 microns thickness was the major cladding material used. A modified version of the conventional saw tooth design with partial insect proof netting along the sides and UV sheet roll back facility has been found widely adopted in the study area. The frame was built with Galvanized Iron pipes in all the polyhouses surveyed. No farmer was found to adopt low cost framing materials like bamboo splints or arecanut poles.

According to Suseela and Devadas (2012) naturally ventilated single span polyhouses with Gable shaped roof and vertical side walls could be the best suited type for humid tropical climate of Kerala. For polyhouses with larger floor areas (larger than 500 m^2) sawtooth type is advisable. However, literally no Gable shaped polyhouse was seen in the samples surveyed.

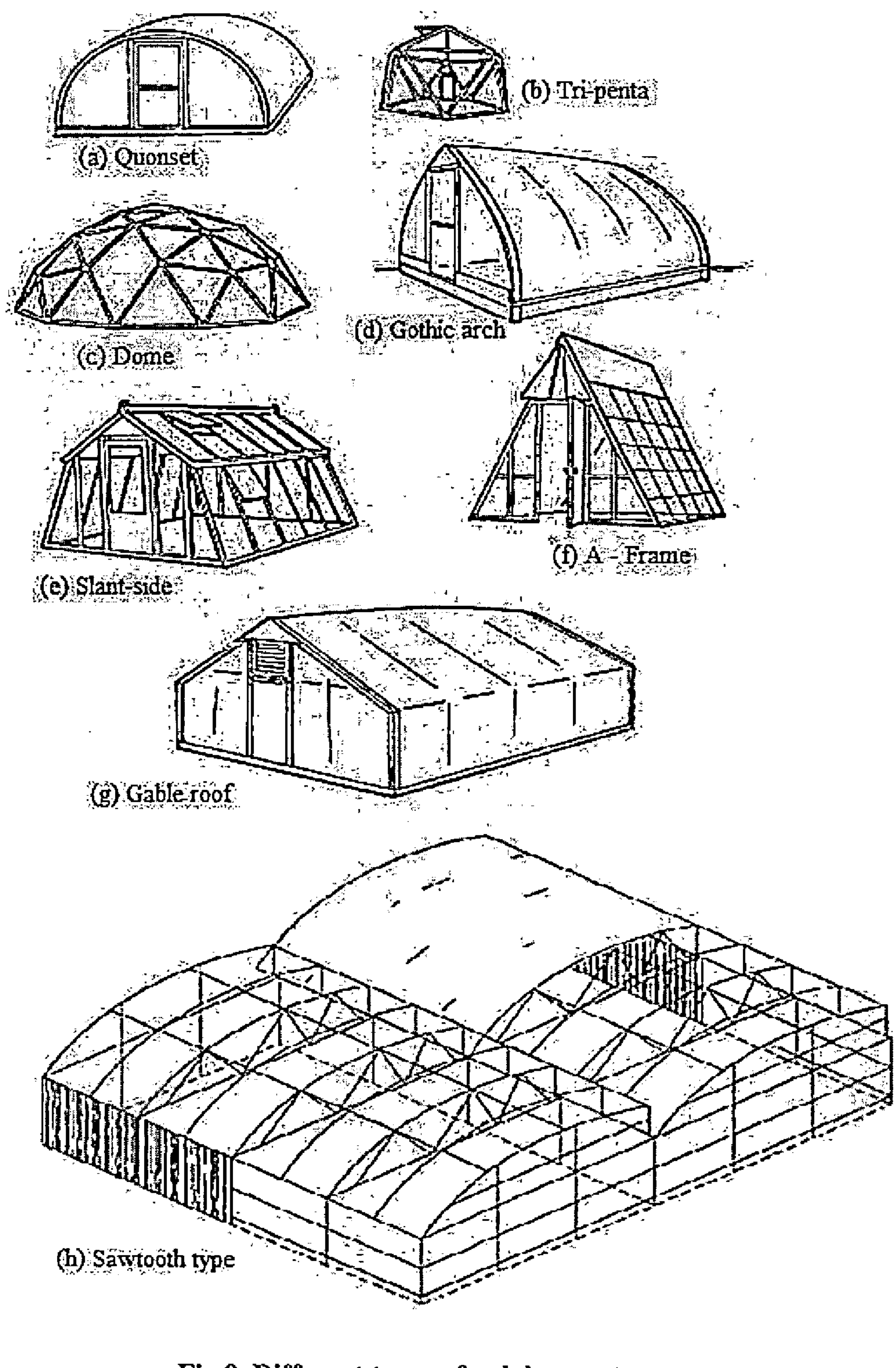

Fig 9. Different types of polyhouse structures

4.2.2. Year of installation of polyhouse

Table 4.9 shows the distribution of polyhouse farmers according to the years in which the polyhouse was installed. Most of the farmers had installed polyhouses during 2013-2014 period. The same trend is observed in both high range and central zone.

Table 4.9. Distribution of farmers based on the year of installation of polyhouse

Year of installation	Number of farmers		Total
	Central zone	High range zone	
Before 2011	0 (0)	1 (5)	1 (2.5)
2011-2012	4 (20)	2 (10)	6 (15)
2012-2013	7 (35)	8 (40)	15 (37.5)
2013-2014	9 (45)	9 (45)	18 (45)
Total	20 (100)	20 (100)	40 (100)

(Figures in parenthesis indicate per cent to total)

The data indicates that polyhouse technology became popular in Kerala since 2011-12 and the maximum number of polyhouses were installed during the year 2013-14 (45%). In the central zone, 35 per cent of the polyhouses and in the high range zone 40 per cent were installed during 2012 - 2013 time period.

This point outs towards the acceptance of polyhouse technology, as indicated by the increased trend of adoption of this technology both in central as well as high range zone.

4.2.3. Area under polyhouse

The distribution of farmers from central and high range zones based on the area under polyhouse is shown in table 4.10. It is evident that majority of the polyhouses from the central zone are having an area between 200 m^2 to 400 m^2 with an average area of 400 m^2. Polyhouses with area between 400 m^2 to 600 m^2 are 10 per cent of the total 20, with an average area of 481m^2. The rest 10 per cent of the polyhouses are having an area between 600m^2 to 800m^2 with an average of 750m^2.

Table 4.10. Distribution of farmers based on the area under polyhouse

Size of polyhouse (m^2)	Central zone		High range zone		Total no. of farmers
	Number of farmers	Average size of polyhouse (m^2)	Number of farmers	Average size of polyhouse (m^2)	
200 and below	0 (0)	-	5 (25)	96	5 (12.5)
201-400	16 (80)	400	7 (35)	400	23 (57.5)
401-600	2 (10)	481	2 (10)	498	4 (10)
601-800	2 (10)	750	2 (10)	800	4 (10)
801-1000	0 (0)	-	3 (15)	1000	3 (7.5)
1001-1200	0 (0)	-	1 (5)	1200	1 (2.5)
Total	20 (100)	-	20 (100)	-	40 (100)

(Figures in parentheses indicate per cent to total)

As in the case of central zone, majority (35 %) of the farmers from high range zone also possess polyhouses with average area of 400m^2. The next prominent class of polyhouse size is below 200m^2. Twenty per cent of the high range zone farmers fall in this category with an average size of 96m^2. Fifteen per cent of farmers possess polyhouses with an average area of 1000m^2. Ten per cent each of polyhouses are having area between 400 m^2 to 600 m^2 and 600m^2 to 800m^2. Polyhouse with an average area 1200m^2 is owned by five per cent of the farmers from the high range zone.

These data reveal that a good number of polyhouses both in central and in high range zone are with an average area of 400m^2. Polyhouses with larger area are comparatively less in central zone than in high range zone. Polyhouses in high range zone shows a wide variability in the area. There are polyhouses as large as 1200m^2 to as small as 40m^2 in the high range zone. Whereas, the polyhouse area is confined to 400m^2 to 800m^2 in central zone.

The observation on size of polyhouse in the study is as accordance with the recommendations put forth by Suseela and Devadas (2012) in a study on engineering designs and adaptations of greenhouse structures suited to Kerala. According to them, the most suited size of polyhouse structure indented for vegetable production for retail business is less than 500 m^2.

4.2.4. Vegetables cultivated in polyhouse

A wide variety of vegetables were found cultivated in the polyhouses. The details of crops cultivated in polyhouses in the study locations are shown in Table 4.11.

Table 4.11. Vegetables cultivated in polyhouse

Sl. No.	Crops	Central zone			High range zone		
		No. of farmers cultivating	Average area per farmer (m^2)	Average yield (kg/m^2)	No. of farmers cultivating	Average area per farmer (m^2)	Average yield (kg/m^2)
1.	Salad cucumber	19	258	6.74	6	440	6.62
2.	Cowpea	16	336.25	3.05	15	369.46	2.84
3.	Beans	-	-	-	5	284	1.02
4.	Bittergourd	5	116	4.19	4	222.5	4.04
5.	Amaranthus	2	290	1.17	4	220	1.09
6.	Capsicum	2	120	0.67	3	866.67	3.15
7.	Brinjal	-	-	-	3	526.67	5.07
8.	Tomato	1	40	1.5	2	550	4.77
9.	Cabbage	1	200	1.25	1	200	2
10.	Cauliflower	1	200	1.25	1	200	2
11.	Chilli	1	180	3.89	1	100	2.5
12.	Bhindi	1	200	1.87	1	100	0.25
13.	Musk melon	-	-	-	1	500	3
14.	Coccinea	-	-	-	1	100	0.25
15.	Ginger	-	-	-	1	400	6.25

Cowpea and salad cucumber are the major crops found in polyhouses, nearly 75 per cent of the respondent farmers raised cowpea followed by salad cucumber.

PLATE 2. Salad cucumber and cowpea in polyhouse

Zone wise analysis showed that 19 out of 20 farmers in the central zone cultivated salad cucumber and 16 out of 20 cultivated cowpea. Salad cucumber and cowpea were cultivated by 30 and 75 per cent of the respondents respectively in the high range zone. The average yield per unit area for both the crops showed no much difference in central and high range zones. Still, the average yield reported in the central zone was slightly higher than in the high range zone. The other popular crops cultivated include bitter gourd, amaranthus, capsicum, tomato, cabbage, cauliflower, chilli and bhindi. A wide range of crop diversity was observed in polyhouses of high range zone. Crops like beans, brinjal, musk melon, coccinea and ginger were found to be cultivated in polyhouses of high range zone.

In an attempt to examine the scope and potential of high value vegetable production in greenhouses, Prabhakar *et al.,* (2012) threw light into the possibility of growing new high value vegetables such as cherry tomato, seedless watermelons, icebox melons, baby cucumber, coloured cabbages etc, besides the conventional polyhouses crops such as tomato, cucumber, egg plant and beans.

4.2.5. Subsidy for polyhouse construction

Polyhouse cultivation involves high initial investment for installing the structure. The state government while introducing the scheme has envisaged to promote polyhouses by providing subsidy for construction of the structure. During 2012 – 13 the Kerala state government has implemented a programme to establish three units of naturally ventilated polyhouses of size 400 m^2 in each Grama Panchayat of the state with financial aid from Central government through order no. G.O. (MS) 153/2012/AD dated 21-06-2012 of Department of Agriculture, Government of Kerala. As per the norms of National Horticulture Mission, the total cost of establishment of a naturally ventilated polyhouse of 400m^2 size has been set as Rs. 3.74 lakh (Rs. 935/ m^2). Accordingly each polyhouse unit is eligible for assistance of 75 per cent of the total cost of construction. Out of this, 50 per cent of assistance is from the central government share through State Horticulture Mission – Kerala and 25 per cent of assistance is from the state government share (GOK, 2012). During 2014, NHM came up with a revised plan, wherein 50 per cent of the estimated cost of Rs. 650/ m^2 for artificially ventilated polyhouses and Rs. 250/ m^2 for naturally ventilated polyhouses (limited to 1000 m^2/ beneficiary) has been fixed as the pattern of assistance for small and marginal farmers. Whereas, it is 33.3 per cent of the estimated cost for other category of farmers. Along with this, the state government share of 25 per cent continued. The programme being implemented in a credit linked manner; those who are willing to avail bank loan for polyhouse construction alone were selected as beneficiaries. The financial assistance is directed to the bank account of the beneficiaries. The subsidy received by the sample respondents for polyhouse construction is presented in Table 4.12.

Table 4.12. Subsidy received for polyhouse construction

Size of polyhouse	200 m^2 and below	201 m^2 – 400 m^2	401 m^2 – 600 m^2	601 m^2 – 800 m^2	801 m^2 – 1000 m^2	1001 m^2 – 1200 m^2
No. of farmers	5	23	4	4	3	1
Subsidy received per m^2 (Rs/ m^2)	490.83	689.45	607.76	458.26	424.83	341.66

The size of polyhouses in the study location ranges from below 200 m^2 to above 1000m^2; accordingly it has been classified into five groups based on the size. Farmers receive subsidy for construction of polyhouse based on the size of polyhouse and the degree to which the constructed polyhouse stick on to the specifications proposed by Government of Kerala. The most widely adopted polyhouses of size ranging from 201m^2 – 400m^2 received subsidy of Rs. 698.45 per m^2 as 75per cent of total cost of its construction. As the size of polyhouse increases the subsidy received per m^2 decreases. This may be attributed to the fact that, as the size increases the economies of scale operates and cost of construction per m^2 decreases and thus the subsidy also decreases. The largest group of polyhouses received Rs. 341.66 per m^2 as subsidy. But, the smallest polyhouse group (200m^2 and below) in the study location received subsidy to a tune of Rs. 490.83 per m^2 because most of them were not adhering to the standard specifications of polyhouse by GOK.

4.3. Economic analysis of vegetable cultivation

An inquiry into the economics of cultivation of vegetables in polyhouse has been attempted. It would be incomplete if not compared with that of conventional open field cultivation. This chapter deals with the detailed economic analysis of polyhouse and open field vegetable cultivation to reveal the extent of profitability of these enterprises.

The survey indicated that majority of the farmers owned polyhouses of area 400m^2. Salad cucumber and cowpea were the commonly cultivated polyhouse crops in the study area. Hence, economic analyses were conducted for the crops salad cucumber and cowpea and for a polyhouse of standard size 400m^2. Comparative studies were done for cowpea alone, as farmers cultivating salad cucumber in open field were not available. Crop sequence with cowpea – salad cucumber – cowpea was observed as the most common one in polyhouses; hence an attempt was also made to determine the economic feasibility of this crop sequence.

The economic analysis has been attempted for the following situations:

1. Comparison of resource use in polyhouse and open field cultivation of cowpea
2. Resource use efficiency in polyhouse and open field vegetable cultivation

3. Returns to scale of polyhouse and open field vegetable cultivation
4. Economic feasibility of production of vegetables in polyhouse
5. Economic feasibility of cowpea cultivation in polyhouse and open field – A comparison
6. Economic feasibility of polyhouse vegetable cultivation, after accounting for subsidy factor.

4.3.1 Comparison of resource use in polyhouse and open field cultivation of cowpea

A comparison of the use of input resources per unit area in the polyhouse cultivation of cowpea is compared with open field cultivation of cowpea.

Table 4.13 Comparison of resource use in polyhouse and open field cultivation of cowpea

Particulars	Mean		t value
	Polyhouse cultivation	Open field cultivation	
Value of seeds (Rs./m^2)	0.99	0.22	6.48**
Value of hired human labour (Rs./m^2)	18.23	16.41	0.536
Value of family labour(Rs./m^2)	33.31	39.35	0.47
Expenditure on transportation (Rs/m^2)	0.55	0.51	0.30
Quantity of soil ameliorants (kg/m^2)	0.26	0.08	2.61**
Quantity of manures (kg/m^2)	2.73	5.94	2.36*
Quantity of chemical fertilizers (kg/m^2)	0.05	0.04	0.14
Quantity of PPC (g/m^2)	4.03	5.54	1.73
Quantity of Bio control agents (g/m^2)	18.50	2.04	2.87*
Production (kg/m^2)	2.89	1.51	2.76**

** - Significant at 1% level
* - Significant at 5% level

Table 4.13 shows the comparison of resource use in polyhouse and open field cultivation of cowpea. The results of t test revealed that, the value of seeds, quantity of soil ameliorants, manures and bio control agents used have significant difference in polyhouse cultivation of cowpea over conventional open field cultivation.

The value of seeds used for cultivation is significantly higher in polyhouse cultivation than in open fields. A significant enhanced use of soil ameliorants is evident in polyhouse cultivation (The quantity of soil ameliorant applied in polyhouse cultivation is 0.26 kg per m^2; while in open field cultivation it is 0.08 kg). The quantity of manures applied was observed to be significantly high (5.94 kg/m^2) in open field cultivation of cowpea than polyhouse cultivation (2.73 kg/m^2) and the quantity of biocontrol agents applied in poly hose cultivation (18.50g/m^2) was found to be significantly higher than that in open field cultivation (2.04g/m^2).

Along with the inputs, the outputs also showed a significant positive difference in terms of production per unit area in polyhouse cultivation than in open field cultivation. Cowpea yields 2.89 kg per m^2 of area in polyhouse whereas the yield is only 1.51 kg per m^2 in conventional open field cultivation.

4.3.2 Resource use efficiency in polyhouse and open field vegetable cultivation

In any production situation, a properly estimated production function could provide a wealth of theoretically appropriate information to guide farmers in their input and output decisions (Biddle, 2010). In this study, Cobb-Douglas production function was fitted for finding out the resource use efficiency and predicting the net returns per unit area of salad cucumber in polyhouse and cowpea in polyhouse and open field cultivation. The production functions, the standard errors of partial regression coefficients and adjusted coefficients of determinations of the different equations are presented in Table 4.14, Table 4.16 and Table 4.18 respectively.

$$Y = a X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} X_7^{b7} X_8^{b8}$$

$Y = \ln y$ and $X_i = \ln x_i$ is the form of production function used

Where, y = Net returns/m^2 (Rs/m^2)

x_1 = Value of seeds used/m^2 (Rs/m^2)

x_2= Value of hired human labour utilized/m^2 (Rs/m^2)

x_3 = Value of family labour utilized/m^2 (Rs/m^2)

x_4 = Transportation charges incurred/m^2 (Rs/m^2)

x_5 = Quantity of soil ameliorants applied/m^2 (kg/m^2)

x_6 = Quantity of manures applied/m^2 (kg/m^2)

x_7 = Quantity of fertilizers applied/m^2 (kg/m^2)

x_8 = Quantity of plant protection chemicals and bio control agents applied/m^2 (g/m^2)

4.3.2.1 Resource use efficiency of cowpea cultivation in polyhouse

Cobb- Douglas production function was fitted to find out the resource use efficiency of cowpea cultivation in polyhouse. The best model was identified using backward elimination method. The result of stepwise regression and backward elimination is presented in the Table 4.14.

Table 4.14. Cobb – Douglas production function for cowpea cultivation in polyhouse

Sl. No	Cobb – Douglas production function	R^2	Adjusted R^2
1	$Y=1.055-0.43X_1+1.08X_2+.11X_3-.47X_4+0.11X_5+0.37X_6+0.83X_7-0.03X_8$	0.73	0.41
2	$Y=1.159+1.06X_2{}^{*}+0.11X_3-0.47X_4+0.12X_5+0.37X_6+0.85X_7-0.024X_8$	0.73	0.49
3	$Y=0.99+1.11X_2{}^{*}+0.10X_3-0.46X_4+0.12X_5+0.36X_6+0.08X_7$	0.72	0.54*
4	**$Y=1.39+0.98X_2{}^{**}+0.08X_3-0.36X_4+0.42X_6{}^{**}+0.12X_7$**	**0.72**	**0.57****
5	$Y= 0.33+1.17X_2{}^{**}+0.09X_3-0.47X_4{}^{*}$	0.64	0.50*

** - Significant at 1% level
* - Significant at 5% level

It could be seen that the value of adjusted coefficient of determination of first production function was 0.41 using all the eight regressors. But, none of the regression coefficients were significant. Using backward elimination process, the least contributing variable was removed and again a Cobb-Douglas production function was fitted. The adjusted R^2 could be improved to a value of 0.49. This procedure was repeated and ultimately, the best model for prediction was identified based on maximum value of adjusted R^2 and checking the absence of multicollinearity among regressors using the VIF criterion.

The fourth model from Table 4.14. was selected as the best model for prediction. Using this model, 57 per cent of variation in net returns per unit area could be explained. From this model it was evident that the variables X_2 (value of hired labour/m^2) and X_6 (quantity of manures used /m^2) have significant positive results in increasing the net returns per m^2. This indicated that the production of cowpea in polyhouse could be increased by increasing the amount of manures applied and increasing the hired human labour employed.

The contribution of regressors towards change in returns per unit area of the selected Cobb Douglas model is discussed in Table 4.15.

Selected model: $Y=1.39+0.98X_2^{**}+0.08X_3-0.36X_4+0.42X_6^{**}+0.12X_7$

** - Significant at 1% level
* - Significant at 5% level

Table 4.15. Contribution of regressors towards change in returns per unit area

For 1% change in ln X_i	**% change in lnY (Net returns/m^2)**
Value of hired labour/m^2 (X_2) (Rs./m^2)	0.98
Value of family labour/m^2 (X_3) (Rs./m^2)	0.08
Expenditure on transportation/m^2 (X_4) (Rs./m^2)	-0.36
Quantity of manures applied/m^2 (X_6) (kg./m^2)	0.42
Quantity of fertilizers applied/m^2 (X_7) (kg./m^2)	0.12

Table 4.15. shows the percentage change in net returns per unit area for a one per cent change in the variables. Value of hired labour and quantity of manures applied were found to be significant at one per cent level. For every one per cent addition in the value of hired labour 0.98 per cent increment in the net returns per unit area was observed. This may be due to the efficiency of hired human labour over family labour which adds to the total production and thus increasing the net

returns per unit area. Effect of application of manures captured through net returns per unit area is 0.42 per cent. The quanity of manures applied improves the general physical condition of soil in polyhouse and thus helps in better nutrient intake by plants resulting in increased production and returns per unit area. All the variabes except expenditure on transportation showed a positive relationship with net returns per unit area. Expenditure on transportation has an inverse relationship as indicated by 0.36 per cent reduction in net returns for every one per cent increment in transportation expenditure.

4.3.2.2 Resource use efficiency of salad cucumber in polyhouse

Cobb- Douglas production function was fitted to find out the resource use efficiency of salad cucumber cultivation in polyhouse. The best model was identified using backward elimination method based on maximum value of adjusted R^2 and checking the absence of multicollinearity among regressors using the VIF criterion. (Refer Appendix I) Table 4.16 shows the best fit model identified after performing backward elimination method.

Table 4.16. Best fit model after performing backward elimination method for salad cucumber cultivation in polyhouse

Sl. No	Cobb – Douglas production function	R^2	Adjusted R^2
1.	$Y = 5.9-0.46X_1^{*}+0.29X_2^{*}+0.72X_4+0.26X_5^{**}-0.27X_7^{*}$	0.76	0.59*

** - Significant at 1% level
* - Significant at 5% level

The selected model could explain 59 per cent variations in net returns per unit area. It is also evident that the variables X_1 (Value of seed/m^2), X_2 (value of hired labour/m^2), X_5 (Quantity of soil ameliorants applied/m^2) and X_7 (Quantity of fertilizers applied/m^2) are the significant variables. The variables, value of seed/m^2, value of hired labour/m^2, quantity of fertilizers applied/m^2 were significant at five per cent level and quantity of soil ameliorants applied/m^2 was significant at one per cent level.

The contribution of regressors towards change in net returns per unit area of the selected Cobb Douglas model is discussed in Table 4.17.

Model specified is, $Y = 5.9-0.46X_1{}^*+0.29X_2{}^*+0.72X_4+0.26X_5{}^{**}-0.27X_7{}^*$

** - Significant at 1% level
* - Significant at 5% level

Table 4.17. Contribution of regressors towards change in net returns per unit area

For 1% change in lnX_i	**% change in lnY (Net returns/m^2)**
Value of seed/m^2 (X_1) (Rs./m^2)	-0.46
Value of hired labour/m^2 (X_2) (Rs./m^2)	0.29
Expenditure on transportation/m^2 (X_4) (Rs./m^2)	0.72
Quantity of soil ameliorants applied/m^2 (X_5) (kg./m^2)	0.26
Quantity of fertilizers applied/m^2 (X_7) (kg./m^2)	0.27

The percentage change in net returns per unit area for a one per cent change in the variables is shown in Table 4.17. As seed is a significant factor which adds to the cost of production of salad cucumber, the value of seeds shows an inverse relation with net returns per unit area. Net returns decreases by 0.46 per centage for every one per cent increase in value of seeds. Value of hired labour utilized improves the production and thus increases the net returns per unit area by an extend of 0.29 per cent. For every one per cent addition of quantity of soil ameliorents applied a 0.26 per cent increment in net returns per unit area is expected. Likewise as the quantity of fertilizer applied increases by one per cent there will be 0.27 per cent increase in net returns per unit area.

4.3.2.3 Resource use efficiency of cowpea cultivation in open field

Cobb- Douglas production function was fitted to find out the resource use efficiency of cowpea cultivation in open field. The best model was identified using backward elimination method based on maximum value of adjusted R^2 and checking the absence of multicollinearity among regressors using the VIF criterion. (Appendix I) Table 4.18. shows the best fit model identified after performing backward elimination method.

Table 4.18. Best fit model after performing backward elimination method for cowpea cultivation in open field

Sl. No	Cobb – Douglas production function	R^2	Adjusted R^2
1	$Y = 4.23+0.60X_1^{**}-0.49X_6^{**}+0.08X_7^{*}+0.66X_8^{**}$	0.96	0.94**

** - Significant at 1% level
* - Significant at 5% level

Ninety four per cent of variation in net returns per unit area could be explained by the best fit model selected. The significant variable identified are X_1 (value of seed/m^2), X_6 (quantity of manures applied/m^2), X_7 (quantity of fertilizers applied/m^2), X_8 (quantity of PPC & bio-control agents applied/m^2). The variables, X_1 (value of seed/m^2), X_7 (quantity of fertilizers applied/m^2) and X_8 (quantity of PPC &

bio-control agents applied/m^2) were found significant at one per cent level and X_7 (quantity of fertilizers applied/m^2) was found significant at five per cent level.

The contribution of regressors towards change in net returns per unit area of the selected Cobb Douglas model is discussed in Table 4.19.

Selected model: $Y = 4.23+0.60X_1{}^{**}-0.49X_6{}^{**}+0.08X_7{}^{*}+0.66X_8{}^{**}$

** - Significant at 1% level
* - Significant at 5% level

Table 4.19. Contribution of regressors towards change in net returns per unit area

For 1% change in lnX_i	**% change in lnY (Net returns/m^2)**
Value of seed/m^2 (X_1) (Rs./m^2)	0.60
Quantity of manures applied/m^2 (X_6) (kg./m^2)	-0.49
Quantity of fertilizers applied/m^2 (X_7) (kg./m^2)	0.08
Quantity of PPC & Bio-control agents applied/m^2 (X_7) (g./m^2)	0.66

The percentage changes in net returns per unit area for a one per cent change in variables are explained in the Table 4.19. Value of seeds used, quantity of manures and fertilizers applied and the quantity of PPC and biocontrol agents used are the significant factors which determine the net returns per unit area. The value of seed used has a positive influence on net returns per unit area. This may be due to the reason that, when farmers use high yielding varieties having comparatively higher price, the yield increases significantly which is reflected in higher net returns. It is estimated that for a one per cent increase in value of seed used there will be 0.6 per cent increment in the net returns per unit area. It is noteworthy that the quantity of manures used has a negative effect on net returns per unit area. It indicates that the monetary benefit derived from application of each additional unit quantity of manure is less than the cost of manure applied per unit area and thus it reduces the net returns per unit area. The higher cost of manures, low market price for produce etc might not make application of manure a better off situation. It has been worked out that for every one per cent addition in quantity of manure applied per unit area the net return reduces by 0.49 per cent. The quantity of the manures applied might be a limiting factor which needs further exploration. Quantity of chemical fertilizers applied was also found to increase net returns per unit area. As the quantity of fertilizers increases by one per cent there will be a 0.08 per cent rise in net returns per unit area. Quantity of biocontrol agents and plant protection chemical applied are also seen to positively influence the net returns.

4.3.3 Returns to scale in polyhouse and open field vegetable cultivation

Returns to scale explain the behavior of rate of increase or decrease in output (production) relative to the associated increase in the inputs (factors of production) in the long run.

In this study, to get a comprehensive idea about the resource use efficiency in polyhouse and open field cultivation of vegetables returns to scale has been found out. In a Cobb-Douglas production function, the sum of coefficients of variables gives information about the returns to scale. Here returns to scale has been worked out for each situations under study *viz,* polyhouse cultivation of salad cucumber, polyhouse cultivation of cowpea and open field cultivation of cowpea. The results are shown in Table 4.20.

Table 4.20. Returns to scale in polyhouse and open field vegetable cultivation

Situation	Returns to scale
Polyhouse cultivation of Salad cucumber	1.60
Polyhouse cultivation of Cowpea	1.57
Open field cultivation of Cowpea	2.01

Returns to scale of various cultivation situations are discussed in Table 4.20. Returns to scale in all the cultivation situations worked out to more than one; indicating that cultivation of salad cucumber and cowpea under polyhouse and cowpea in open field conditions are having increasing returns to scale. The lowest value was observed in polyhouse cultivation of cowpea.

4.3.4 Efficiency ratio of vegetable cultivation in polyhouse and open field

The efficiency of resource use was further ascertained by estimating the Efficiency ratio (r) of each significant input at the farm gate price for output and market price for inputs in all the cultivation situation to obtain a comprehensive stance on the resource use efficiency of polyhouse cultivation and its dissimilarities with open field cultivation.

Table 4.21. Estimated efficiency ratio of cowpea cultivation in polyhouse

Resources	MVP	MFC	Efficiency ratio (r)
Hired human labour	0.57	16.16	0.03
Family labour	0.02	23.71	0.001
Transportation	6.98	0.49	14.13
Manures	1.63	14.02	0.11
Fertilizers, growth promoters	23.4	6.43	3.63

Efficiency ratios were computed for the factors of production which significantly influence the changes in output level such as hired human labour, family labour, transportation, manures, fertilizers and growth promoters in the case of polyhouse production of cowpea. From Table 4.21, it is clear that none of the inputs in the polyhouse production of cowpea has been efficiently utilized to optimum economic advantage. It is observed that resources such as hired human labour, family labour and manures applied have been over utilized. Considering the higher price of quality manure and increasing wage rate of laboures, an optimum utilization of such resources is necessary to bring the cowpea cultivation in polyhouses into profitable level. At the same time, cowpea production in polyhouses is likely to increase if the allocation for resources such fertilizers, growth promoters and transportation is increased from the present levels.

Table 4.22. Estimated efficiency ratio of salad cucumber cultivation in polyhouse

Resources	MVP	MFC	Efficiency ratio (r)
Seed	-0.93	13.6	-0.07
Hired human labour	0.511	19.83	0.02
Transportation	24	0.72	33.3
Soil ameliorants	12.2	3.17	3.86
Fertilizers, growth promoters	-67.16	8.16	-8.23

Table 4.22 shows the MVP, MFC and efficiency ratio of resources used in polyhouse cultivation of salad cucumber. The overutilized resources are seed, hired human labour, fertilizers and growth promoters as indicated by efficiency ratios less than unity. The reduced use of inputs or use of cheap sources of seeds, fertilizers growth promoters and hired labour is expected to increase the profitability. Whereas

the inputs soil ameliorants and expenditure on transportation are underutilized in the polyhouse cultivation of salad cucumber.

Table 4.23 Estimated efficiency ratio of cowpea cultivation in open field

Resources	MVP	MFC	Efficiency ratio (r)
Seed	0.32	0.20	1.55
Manures	-0.10	4.16	-0.02
Fertilizers & growth promoters	1.80	1.49	1.21
Plant protection chemicals and bio-control agents	0.10	1.12	0.09

Table 4.23 reveals that the ratio of MVP and MFC are greater than unity for all the inputs except manures, plant protection chemicals and bio-control agents in the cultivation of cowpea in open filed. In case of seeds, fertilizers and growth promoters, the values of MVP and MFC are more or less equal. Which indicate that, farmers derive nearly maximum economic advantage from each unit of inputs such as seeds, fertilizers and growth promoters utilized in the open field cultivation of cowpea. It is also noteworthy that manures, plant protection chemicals and bio-control agents are over utilized in open field cultivation. And reduction in its usage would lead to maximization of profit.

When judged against the economic efficiency of the same inputs (fertilizers and growth promoters) used in polyhouse cultivation of cowpea, the economic efficiency in open field cultivation is seem advantageous. Cultivation of cowpea in open field utilizes inputs more efficiently as indicated by the efficiency ratios of seeds, fertilizers and growth promoters which are approximately equal to unity. It is also striking that transportation is one of the major underutilized resource in polyhouse cultivation (cowpea and salad cucumber) this indirectly indicates the possibility of widening markets for polyhouse products rather than sticking on to domestic or farm gate sale where the farmer incur no or less cost on transportation.

4.3.5 Economic feasibility of production of vegetables in polyhouse

Review of literature on polyhouse cultivation categorizes three different types of costs viz, fixed cost, annual variable cost and seasonal variable cost (Murthy *et al.*, 2009). Fixed costs include the cost of establishment of polyhouse. Costs of inputs like plastic mulch, twines, propping, pandal materials, soil solarisation chemicals etc. that are used annually are accounted as annual variable cost. Seasonal cost includes cost incurred on inputs that are used for each cropping season such as seeds, fertilizers, manures, plant protection chemicals etc.

a) Fixed cost

Establishment of polyhouse warrants a huge capital initially which contributes to the major component of cost of production. The various components of establishment and their costs are detailed in Table 4.24. It requires Rs.4,54,330 for constructing a polyhouse of $400m^2$ area (Rs. 1,136 / m^2). This comprises of cost of GI pipe assembly, aluminium channels, UV stabilized polythene sheet of 200 microns thickness, antivirus and shade nets of 40 mesh size, drip irrigation and fertigation unit (ventury), fogger for microclimatic regulation and labour charges for erection and fabrication. The UV stabilized polythene sheet usually last for 4-5 years and has to be replaced on wear and tear.

Out of the total initial establishment cost, the major share was incurred on GI pipe assembly (43%), followed by labour charges on erection and fabrication (18 %). Ten percentage of the total cost was incurred on irrigation and fertigation unit. UV stabilized polythene sheet and aluminium channel accounts for seven and four per cent of total establishment cost. Three percentages each of total establishment cost was incurred on antivirus net, shade net and fogger. Miscellaneous costs include the cost of initial land preparation, bund formation, contractors profit etc. This account for seven per cent of the total establishment cost.

Table 4.24. Cost of establishment of polyhouse

Sl. No	Particulars	Cost (Rs.)	
		Per 400m^2	per m^2
1.	GI Pipe assembly	196900 (43)	492.25
2.	Aluminum channel	20160 (4)	50.4
3.	UV Stabilized sheet	34040 (7)	85.1
4.	Antivirus net	1359 (3)	33.97
5.	Shade net	14700 (3)	36.75
6.	Irrigation system & fertigation unit	45680 (10)	114.2
7.	Microclimatic regulation system (fogger)	15000 (3)	37.5
8.	Erection & fabrication charges	84260 (18)	210.65
9.	Miscellaneous	30000 (7)	75
	Total	454330 (100)	1135.82

(Figures in parentheses indicate per cent to total)

b) Annual variable cost

The costs incurred on inputs which last for one year are grouped as annual variable cost. Items of annual variable costs are listed in Table 4.25. It includes inputs such as twines and propping materials, soil solarisation chemicals and plastic mulch which are used annually during the production process.

As the crop duration is four months for salad cucumber and cowpea three crops could be taken in a year in a sole cropping situation. Hence, the cost of inputs that last for three cropping seasons of salad cucumber and cowpea are listed as annual variable cost of sole crop of salad cucumber and cowpea. The cost incurred on inputs for the cultivation of cowpea – salad cucumber – cowpea in a sequence in a year are accounted as annual variable cost of the crop sequence.

Table 4.25. Annual variable costs of sole crop of salad cucumber, cowpea and cowpea – salad cucumber – cowpea sequence

Sl. No	Item	Cost (Rs./ 400m^2)		
		Salad cucumber	Cowpea	Cowpea – salad cucumber – cowpea
1.	Twines, propping materials	1172 (32 %)	1172 (72 %)	1172 (31 %)
2.	Plastic mulch	2497 (68 %)	350 (21 %)	2497 (66 %)
3.	Soil solarisation chemical	-	108 (7 %)	108 (3 %)
	Total	3669 (100 %)	1630 (100 %)	3777 (100 %)

(Figures in parentheses indicate per cent to total)

The average annual variable cost for cultivation of salad cucumber in polyhouse was estimated to be Rs. 3669 per 400 m^2 and that of cowpea was Rs. 1630 per 400 m^2 and cowpea – salad cucumber – cowpea sequence was Rs. 3777. Rs. 2497 was incurred on plastic mulch for an area of 400 m^2 in the sole cultivation of salad cucumber and cultivation involving cowpea – salad cucumber – cowpea sequence. Although, a few farmers cultivating sole crop of cowpea was found to use plastic mulches in polyhouses, hence on an average the expense on plastic mulch in the sole cultivation of cowpea is around Rs. 350 as majority of the cowpea farmers are not using plastic mulch in polyhouse. Expense on twines and propping materials was Rs. 1172 in all the cases. Soil solarisation chemicals were not observed to be used in the cultivation of salad cucumber in polyhouse.

Though it is a standard recommendation to adopt soil solarization in polyhouse cultivation, none of the farmers cultivating sole crop of salad cucumber were found to adopt this method using chemicals. Most of them believed that chemical soil solarisation will destroy the natural fertility of soil. Even then, soil solarisation employing physical measures with the help of plastic mulch was found common in salad cucumber cultivation.

However, chemical soil solarisation was found common in polyhouse cultivation of cowpea. Formaldehyde and Hydrogen peroxide were the commonly used chemicals. Increased susceptibility of cowpea to soil borne diseases and nematodes might have caused the wide adoption of chemical soil solarisation in the cultivation of cowpea.

c) Seasonal variable cost

The details of seasonal variable cost incurred on the polyhouse cultivation of salad cucumber and cowpea are shown in Table 4.26. It accounts for the cost of variable inputs that are used during each cropping season.

For cultivating salad cucumber or cowpea as a sole crop, farmers incur seasonal variable cost of salad cucumber or cowpea for the entire 3 seasons in a year. In polyhouses where cowpea – salad cucumber – cowpea sequence is followed, farmers incur seasonal variable cost of cowpea for the first and last seasons and that of salad cucumber in the second season.

Since family labour contributes a significant part to the total labour use in the cultivation, an imputed value of family labour has been included along with the paid out costs. The survey indicated that, all of the polyhouses surveyed were erected in the own land of farmers, in this respect, a cost on land lease was not incurred by farmers; hence not included as a variable cost. Even though, polyhouse cultivation requires substantial amounts of power for running the automated fertigation and irrigation units; farmers are not incurring any cost on electricity, as electricity for agricultural purpose is free of cost in the state.

Table 4.26. Seasonal variable cost of polyhouse cultivation of salad cucumber and cowpea

Sl. No.	Item	Cost (Rs./ 400m^2)	
		Salad cucumber	Cowpea
1.	Seed	5452 (13 %)	352 (1 %)
2.	Hired human labour	7932 (20 %)	6464 (25 %)
3.	Machinery	118 (0.4 %)	0 (0 %)
4.	Manures	5457 (13 %)	5609 (21%)
5.	Fertilizers, growth promoters	3268 (8 %)	2574 (10 %)
6.	PPC and bio control agents.	959 (2 %)	272 (1 %)
7.	Soil ameliorants	1266 (3 %)	1044 (4%)
8.	Packing materials & post harvest handling	269 (0.8 %)	0 (0%)
9.	Transportation	289 (0.8 %)	197 (1 %)
10.	Family labour	15599 (39 %)	9486 (37 %)
	Total	40609 (100 %)	25998 (100 %)

(Figures in parentheses indicate per cent to total)

The average seasonal variable cost for salad cucumber in polyhouse was worked out to be Rs. 40609 per 400m^2, that of cowpea was Rs. 25998 per 400m^2. The higher cost for salad cucumber was due to notably high cost on seeds, plant protection chemicals, bio control agents and higher involvement of family labour as indicated by a high value of imputed family labour than that on cowpea. It is also noteworthy that cost on machine labour, packing materials and post harvest handling was not incurred in the cultivation of cowpea. Production of cowpea does not involve any sorting, packing or post harvest handling and is either sold out via farm gate sale or in the local retail markets. Whereas, salad cucumber is subjected to minimal visual sorting for length and presence of thrones and is packed before marketing. Salad cucumber is usually packed in plastic cling films or card board crates of 2 or 5 kg capacity. The major sale centers of salad cucumber are supermarkets.

In both the crops, the breakup of cost indicated that highest cost was incurred for labour followed by manures, fertilizers, growth promoters and soil ameliorants. Hired human labour is mainly employed for initial land preparation application of soil ameliorants and basal dose of fertilizers. For all other purposes family labour is utilized. Salad cucumber requires more labour for training, pruning and harvesting than cowpea. This is the reason for high imputed value of family labour in salad cucumber cultivation.

In the case of salad cucumber, the cost of seed is a significant factor which adds to the seasonal variable cost. Only parthenocarpic hybrid seeds are used in polyhouse cultivation of salad cucumber. The generally observed seed rate was 750 – 1000 numbers/ 400m^2. All of the surveyed respondents were relying on private seed companies for salad cucumber seeds. On an average a farmer spends Rs. 6.3 for a single seed of salad cucumber.

In a similar study to analyse the economics of organic greenhouse lettuce production in Turkey Engindeniz and Tuzel (2006) suggest that organic green house lettuce production is an economically viable alternative for growers, although the initial and total costs of organic lettuce production were higher compared to conventional production.

d) Returns

The average yield of salad cucumber is 3132 kg/ 400m^{2}per season. The price received by farmers range from Rs. 30 to 40 per Kg. Hence the average farmer's price has been taken as Rs. 35/ kg. The average yield of cowpea is 1167kg/ 400m^2 per season and the average farm gate price is Rs. 41/ kg.

Table 4.27. discusses the net returns per year of polyhouse cultivation of sole crop of salad cucumber, sole crop of cowpea and crop sequence involving two alternate crops of cowpea and a crop of salad cucumber.

Table 4.27. Net returns of polyhouse vegetable cultivation

Sl. No.	Crop	Returns per year (Rs./400m^2)
1.	Salad cucumber – salad cucumber – salad cucumber	328716
2.	Cowpea – cowpea – cowpea	143590
3.	Cowpea – salad cucumber – cowpea	210003

4.3.5.1 Capital productivity analysis

The economic feasibility of cultivation of sole crop of salad cucumber, cowpea and the crop sequence cowpea – salad cucumber – cowpea were evaluated using Capital Productivity Analysis. Payback Period (PBP), Benefit Cost Ratio (BCR), Net Present Value (NPV) and Internal Rate of Returns (IRR) are the measures of Capital Productivity Analysis. The details of Capital Productivity Analysis are given in Table 4.28.

Table 4.28. Economic feasibility of polyhouse vegetable cultivation

Sl. No.	Economic feasibility Indicators	Salad cucumber	Cowpea	Cowpea – salad cucumber – cowpea sequence
1.	Payback Period (Years)	3.2	8.4	5.2
2.	Benefit Cost Ratio*	1.5	0.83	1.1
3.	Net Present Value * (Rs./400m^2)	530864	-131600	104600
4.	Internal Rate of Returns (%)	42	2	19

* at 12 % discount rate

In the polyhouse cultivation of sole crop of salad cucumber throughout the year, the payback period was found to be 3.2 years. Considering the large amount of initial investment made, 3.2 years is a reasonable time to get back this initial outlay of money. Net present value (NPV) for 10 years worked out to Rs. 5.30 lakhs/ 400m^2 with a Benefit Cost ratio (BCR) of 1.5 at 12 per cent discount rate. The Internal Rate of Returns (IRR) for the cultivation of salad cucumber in polyhouse is sufficiently high at 42 per cent per annum. Thus, all the economic indicators point out that the cultivation of salad cucumber in polyhouse is economically feasible and profitable.

In the sole cultivation of cowpea in polyhouse, the payback period was found to be 8.4 years. The Benefit Cost ratio was worked out to be 0.83 and Net present value was less than zero at 12 per cent discount rate. Internal Rate of Returns was estimated as two per cent per annum. All the measured parameters indicated that the cultivation of sole crop of cowpea in polyhouse is not economically feasible.

When the crop sequence (cowpea – salad cucumber – cowpea) is considered, the payback period worked out to 5.2 years. Net present value came to 1.04 lakhs/ 400m^2 at 12 per cent discount rate, with a benefit cost ratio of 1.1. The internal rate of returns was found to be 19 per cent per annum for the crop sequence. Hence, it can be concluded that cultivation of crop sequence involving 2 crops of cowpea (first and last crop) and one crop of salad cucumber (second crop) is an economically feasible one.

Murthy *et al.* (2009) in a study examining the economic viability of production of capsicum and tomato in naturally ventilated polyhouse at IIHR, Bangalore reported that cultivation of capsicum in polyhouse was highly feasible as reflected in higher values of NPV, BCR and IRR with less than two years of payback period. Whereas production of tomato in polyhouse was found not feasible by examining the project appraisal factors NPV, BCR, IRR and payback period

4.3.6 Economic feasibility of cowpea cultivation in polyhouse and open field – A comparison

As the sole cultivation of cowpea for the entire three seasons in polyhouse was found to be an economically unfeasible venture; a comparison of the economics of cultivation of cowpea in polyhouse with open field is desirable.

Since worked out for comparison, the economics of open field cultivation of cowpea has also been structured in the same fashion as that of polyhouse cultivation of cowpea. Cost of production involves fixed cost, annual variable cost and seasonal variable cost. All costs have been worked out for an area of $400m^2$ (10 cents) of open field cultivation of cowpea. As the crop duration is 4 months, 3 crops can be taken in a year and economics have been worked out for 3 crops of open field cowpea for a year.

Fixed cost accounts for the investment made on basic farm implements, machinery etc. which comes to Rs. 20062 per $400m^2$. Cost of propping materials, coir or plastic ropes for trailing, that a farmer uses for the entire 3 cropping seasons were grouped as annual variable costs; it accounts for Rs. 652 per $400m^2$. Costs of seeds, fertilizers, manures, plant protection chemicals, laboures etc that are incurred for each cropping seasons are included as seasonal variable costs; it adds to Rs. 14979 for a single cropping season of cowpea (Appendix II).

The details of comparison of economic feasibility indicators and returns to scale of cowpea cultivation in polyhouse and open field in 400 m^2 area are given in Table 4.29.

Table 4.29. Economic feasibility of cowpea cultivation in polyhouse and open field – A comparison

Economic indicators	Polyhouse	Open field
Returns (Rs./annum)	143597	41449
Payback Period (Years)	8.4	4.2
Benefit Cost Ratio*	0.83	1.04
Net Present Value * (Rs./400m^2)	-131600.35	7468.28
Internal Rate of Returns (%)	2	23
Returns to scale	1.57	2.01

* at 12 % discount rate

It is clear that the return per annum from cowpea cultivation in polyhouse is markedly higher than that in open field. Nevertheless, the sole cultivation of cowpea in polyhouse has been found economically unfeasible as earlier discussed. Even though the return is lower in open field cowpea cultivation, all the feasibility parameters indicate that open field cultivation is economically viable. The Payback period was 4.2 years in open field cowpea cultivation while it was an unreasonable 8.4 years in polyhouse cultivation. Benefit Cost Ratio was seen above unity in open field cowpea cultivation whereas it was just 0.83 in polyhouse cultivation. Net Present Value was positive in open field cultivation as against a negative NPV in polyhouse cultivation. Internal Rate of Return in open field cultivation also indicates that it is an economically feasible venture. Returns to scale was also found higher in open field cowpea cultivation than in polyhouse.

But, in a study conducted to examine the effect of protected and unprotected conditions on biotic stress, yield and economics of spring summer vegetables at

IARI, New Delhi, Singh *et al.* (2005) reported that gross income, net income and benefit: cost ratios were found higher under protected condition as compared to open field condition in cucumber, summer squash and okra.

While analyzing the comparative economic advantage for hybrid seed production of cucumber Pant Shankar Khira 1 under naturally ventilated polyhouse, insect proof net house and open field condition; Kaddi *et al.* (2014) reported that the insect proof net house was more profitable followed by open condition and naturally ventilated polyhouse was found uneconomical because of its high initial investment.

The results points out at the question of the necessity for adopting high capital intensive poly house technology when no lesser returns could be attained using protected structures or even in open field situation. The environmental concerns of using hugė quantity of polythene materials are yet another concern.

4.3.7 Economic feasibility of polyhouse vegetable cultivation: Considering the subsidy factor

Even though the actual establishment cost is much higher than the estimated cost by government agencies for providing financial aid, the subsidies provided are a great help for the farmers entering into polyhouse cultivation. Farmers are receiving subsidies based on the area of polyhouse. They should also follow the standards prescribed by State Horticulture Mission – Kerala for construction and cultivation. Accordingly, on an average a farmer receives Rs. 2,75,780 as subsidy for a polyhouse of 400 m^2 area (Rs. 690/ m^2).

The economic feasibility has also been worked out considering the subsidy factor. For which, the subsidy amount is deducted from the initial establishment cost (fixed cost), as a result the fixed cost will reduce from Rs. 4,54,330 to Rs. 1,78,550. Cash flow statement was generated with Rs. 1,78,550 as the fixed cost and all other costs remaining the same. The Capital Productivity Analysis was carried out and economic feasibility indicators (Table 4.30.) were generated considering the subsidy factor.

Table 4.30. Economic feasibility of polyhouse cultivation after accounting for subsidy factor

Sl. No.	Economic feasibility Indicators	Salad cucumber	Cowpea	Cowpea – salad cucumber – cowpea sequence
1.	Payback Period (Years)	1.6	3.5	2.5
2.	Benefit Cost Ratio*	1.99	1.2	1.54
3.	Net Present Value * (Rs./400m^2)	777097	114632	350833
4.	Internal Rate of Returns (%)	112	29	61

* at 12 % discount rate

After accounting for the subsidy factor, all the indicators showed improvement in all the cultivation situations. The payback period has reduced from 3.2 years to 1.6 years in case of sole crop of salad cucumber. It is now 2.5 years in case of the crop sequence from an earlier 5.2 years. This means that, the farmers would be able to get back their initial investment on polyhouses almost 2 to 3 years earlier in a subsidy situation. BC ratio has also been improved significantly. NPV has multiplied to several manifolds than the earlier situation. Change in IRR also shows an improved economic viability than the earlier situation.

A remarkable change has been observed in the cultivation of cowpea. The subsidy provided could significantly improve the situation. Payback period has reduced from 8.4 years to 3.5 years. BC ratio has now become more than unity from an earlier 0.83. NPV also shows a significant improvement with a positive and high value in a subsidy situation. IRR has also progressed significantly compared to the earlier situation. All the parameters indicate that the subsidy factor could all over transform the earlier impractical situation into a highly profitable and feasible one.

Economic feasibility analysis considering the subsidy factor points out that, the financial aid provided to farmers significantly improves the economic viability and profitability of polyhouse cultivation of vegetables. It also reduces the financial burden imposed on farmers for establishing polyhouses as it involves a substantial initial investment. As the payback period has reduced to a greater extent, the uncertainty of polyhouse cultivation has also been handled tactically in a subsidy regime.

4.4. Decision making in polyhouse cultivation

The decision making factors which influence the farmers in adopting polyhouse cultivation as well as the major aspects of polyhouse cultivation that farmers perceive as the significant advantages are discussed in detail.

The factors which influence the decision making in adoption of polyhouse cultivation were identified using logistic regression. The two sample groups include the adopters represented by the polyhouse farmers and the non adopters represented by the open field farmers. The variables used for the analysis are: age, education level, occupation status, years of experience in agriculture, family income and land holding size. The result of logistic regression is given in Table 4.31.

Table 4.31. Factors influencing decision making in adoption of polyhouse cultivation

Variables	B (Coefficient)	Standard error	Odds ratio
Age	-0.349	0.550	0.41
Education level	0.740*	0.584	0.68
Occupation	-0.092	0.212	0.48
Experience in agriculture	-0.281	0.362	0.43
Family income	1.070*	0.509	0.74
Land holding size	0.950*	0.536	0.72
Constant	0.416	0.909	-

* - Significant at 5% level

The logistic regression revealed that education level, family income and land holding size are the significant factors which influence the decision making in adoption of polyhouse technology. The coefficients of all these significant variables are positive indicating that there is a direct relationship between the variables and decision making. The result implies that as the education level of farmers is improved they are more likely to tend towards adoption of polyhouse technology. Likewise farmers will be inclined towards polyhouse cultivation as the family income increases. Land holding size, which is an indication of wealth, is also a significant factor that decides the adoption of polyhouse by a farmer. Larger land holding size positively influences the farmer in taking up polyhouse cultivation.

Logistic regression is also used to predict the odds of being a success based on the values of the independent variables (predictors). The odds are defined as the probability that a particular outcome is a success divided by the probability that it is a failure. Here, the odds ratio of the significant variable, education level of farmers is 0.68, which indicates that as the education level of farmers is improved, there is 68 per cent chance that a farmer will go for adoption of polyhouse cultivation over open field cultivation. Likewise, the odds favoring a transition by an increased guaranteed family income was to the extent of 74 per cent with equally favouring odds (72 %) by an extended land holding.

4.4.1 Advantages of polyhouse cultivation as perceived by farmers

For finding out the overall agreement among the farmers in listing out the advantages of polyhouse cultivation, Kendal's coefficient of concordance was used. The χ^2 value was found highly significant at nine degrees of freedom with a confidence level of 99.99 per cent.

Table 4.32. Advantages of polyhouse cultivation of vegetables as perceived by polyhouse farmers

Sl. No.	Statement	Mean rank	
		Central zone	**High range zone**
1.	For consuming safe vegetables and to supply safe vegetables to near and dear	1.60	2.35
2.	Possibility of growing off-season vegetables	2.35	2.05
3.	Better quality produce	3.35	4.15
4.	Higher yield and income	3.95	4.70
5.	Less dependence on external labour for crop management	5.20	5.10
6.	Better management of disease and pest compared to open field	5.50	4.40
7.	Easy crop management	6.25	5.90
8.	As a hobby or post- retirement engagement	7.95	7.50
9.	Potential for export	9.20	9.10
10.	Horticulture therapy	9.65	9.75

S = 27890 Coefficient of concordance, $W = 12\ S/\ K^2\ (n^3 - n)$

Where, K – Number of farmers = 20

n – Number of statements = 10

W = 0.84515 Calculated $\chi^2 = 132.7418$

Tabulated value of $\chi^2 = 27.877$ (at 9 degrees of freedom)

The coefficient of concordance indicates that there is high level of agreement between the farmers in ranking the advantages of polyhouse cultivation. The mean rank assigned for statements highlighting the advantages of polyhouse cultivation as per farmers' perception range from 1.60 to 9.65 in central zone; and 2.05 to 9.75 in high range zone.

Accordingly, among the farmers of central zone the statement which ranked first is the need for consumption of safe vegetables and to supply safe vegetables to near and dear. The possibility of growing off season vegetables was ranked as the second advantage of polyhouse cultivation. The better quality produce obtained from polyhouse cultivation got the third rank. The higher yield and income offered by polyhouses was ranked fourth. Farmers find the less dependence on external labour for polyhouse cultivation as its fifth best advantage. Rank six was given to the possibility of better pest and disease management inside the polyhouse. Easy crop management, likelihood of polyhouse cultivation being a hobby or post retirement engagement and the potential for export it offers came in rank seven, eight and nine respectively. The possibility of including polyhouse cultivation as a part of horticulture therapy was the least ranked advantage among the polyhouse farmers of central zone.

Polyhouse farmers of the high range zone unanimously picked the possibility of growing off-season vegetables as the most important advantage of polyhouse cultivation. The second advantage turned out to be the role of polyhouses in farmer's need of consuming safe vegetables and supplying the same to near and dear. Possibility of growing better-quality produce in polyhouses ranked as the third advantage of polyhouses. The possibility of efficient pest and disease management was chosen as the fourth ranked advantage. The higher yield and income offered by polyhouse cultivation scored the fifth rank. Farmers ranked the advantage of less dependence on external labour in polyhouse cultivation as its sixth advantage. Ease of crop management, polyhouse cultivation as a hobby or post retirement engagement and the potential of polyhouses for export oriented production were ranked seventh, eighth and ninth ranks respectively. Like in the case of response of polyhouse farmers in the central zone, including polyhouse cultivation as part of horticulture therapy was ranked the last tenth rank.

Irrespective of the zones all the polyhouse farmers surveyed were on strong agreement in choosing the possibility of consuming safe vegetables, growing off-season vegetable and the better quality of produce in polyhouse cultivation as its best advantages. From this response it is clear that rather than the monetary benefits from polyhouses it is the quality and the diversity of produce which generally attracted the farmers towards polyhouse cultivation in the study area. The farmers in both the zones were found to give very low priority for the factor 'potential for export' in perceiving the advantages of polyhouse cultivation. Role of polyhouse cultivation in horticulture therapy was identified as the least appreciated advantages.

4.5 Constraints faced by farmers in polyhouse cultivation.

Though polyhouse cultivation of vegetables is a promising new technology adopted worldwide, there are so many limiting factors encountered by polyhouse vegetable farmers of Kerala. In the study, the respondent polyhouse farmers were asked to rank the major constraints of polyhouse cultivation as per their perception. The overall agreement among the famers in ranking the challenges of polyhouse cultivation was found out using Kendal's coefficient of concordance. The χ^2 value was found highly significant at nine degrees of freedom with a confidence level of 99.99 per cent. The results are presented in Table 4.33.

Table 4.33. Challenges in polyhouse cultivation of vegetables as perceived by polyhouse farmers

Sl. No.	Statement	Mean rank	
		Central zone	High range zone
1.	High initial investment	2.25	3.40
2.	Lack of proper technical knowledge	3.40	3.35
3.	Non availability of technical experts in local area	3.80	4.75
4.	No extra premium for better quality produce	4.20	4.50
5.	Non availability of good quality materials for the establishment of polyhouse	6.15	6.45
6.	Prohibiting seed prices	6.15	5.15
7.	Non availability of good quality seeds and planting materials	6.75	6.60
8.	Incidence of pest and diseases	6.85	7.40
9.	Lack of support from government	7.55	6.10
10.	Lack of demand for off season vegetables in the local markets	7.90	7.30

S = 8016 Coefficient of concordance, $W = 12\,S / K^2 (n^3 - n)$

Where, K – Number of farmers = 20

n – Number of statements = 10

W = 0.2429 Calculated $\chi^2 = 43.724$

Tabulated value of $\chi^2 = 27.877$ (at 9 degrees of freedom)

There is high level of agreement between the farmers in ranking the major challenges of polyhouse cultivation as indicated by the Coefficient of concordance. The mean rank of the statements on the constraints in polyhouse cultivation ranged from 2.25 to 7.90 as per farmers' perception in central zone; and 3.35 to 7.30 in high range zone. The polyhouse farmers from central zone ranked the high initial involved in polyhouse as its worst drawback. The lack of technical knowledge among farmers was the second major limitation of polyhouse cultivation. The third major shortcoming identified was the absence or lack of technical experts in local area. The unwillingness of markets in offering premium price for polyhouse grown vegetables for its better quality was rated as the fourth main disadvantage of polyhouse cultivation. The inhibiting high seed prices and non availability of good quality raw materials for the establishment of polyhouse were pointed out as the fifth and sixth ranking disadvantages of polyhouse cultivation. Non availability of good quality planting materials for cultivation was listed as one of the shortcomings of polyhouse and it came in the seventh position. Farmers identified the incidence of pest and diseases, lack of support from government and the lack of demand for off season vegetables as the least troubled problems in polyhouse cultivation compared to others, these were ranked eight, nine and ten respectively.

Lack of technical knowledge regarding polyhouse cultivation was identified as the most challenging crisis faced by polyhouse farmers of high range zone. The second comes to be the huge initial investment required for establishment. No extra premium they receive for better quality polyhouse produce was ranked as the third biggest disadvantage of polyhouse farming. The absence of service of technical experts in local area and the soaring seed prices were also identified as the weaknesses and farmers ranked these a four and five respectively. The sixth ranked constraint was the lack of support from government. Non availability of good quality materials for the establishment of polyhouse, non availability of planting materials and the lack of demand for off-season vegetables in the local markets were found to be the least affected problems by farmers. The tenth rank was assigned to the problem of pest and disease attack in polyhouses by the farmers of high range zone.

All of the polyhouse farmers identified the high initial investment involved, lack of technical knowhow among farmers and non availability of technical experts in local area as the major constraints of polyhouse cultivation in the study area. Even though subsidies exist for the establishment of polyhouse, the high initial investment is a major problem that hinders the adoption of this technology among the farmers. Technicalities of cultivation aspects are found to be another barrier that they encounter throughout polyhouse cultivation as it is entirely different from conventional methods of farming. The farmers also emphasized that they are devoid of any technical help from experts and the study also revealed that most of them are following their own practices which they have developed from their own trials in polyhouse. Service of agricultural officer in providing technical help regarding the same is also meager as most of them are not technically well equipped to offer advices to the farmers. According to the farmers in both central and high range zone, lack of demand for off-season vegetables in the local market and incidence of pest and diseases have never became any constraints in polyhouse cultivation. It is under these circumstances that researches for evolving cost effective technologies becomes significant. Imparting training to labour banks on construction and management of polyhouses also may be appreciable.

4.5.1 Extension Linkages of polyhouse farmers

While discussing on the constraints faced by polyhouse farmers, it was revealed that one of the most challenging issues faced by the farmers is the lack of proper technical knowledge on polyhouse cultivation coupled with non availability of technical experts in their vicinity. In this context, the extension linkages of polyhouse farmers are studied in detail.

4.5.1a. Source of polyhouse technology

The farmers were asked to respond on the source from which they got information on polyhouse technology before its adoption.

Table 4.34. Distribution of farmers based on their source of information on polyhouse technology

Agency	No. of farmers
Govt. Agencies	8 (20)
Other polyhouse farmers	15 (37.5)
Private agencies	7 (17.5)
Media, Journals	10 (25)
Total	40 (100)

(Figures in parentheses indicate per cent to total)

Table 4.34 shows the distribution of farmers based on source of information on polyhouse technology. Out of the 40 farmers surveyed, the majority (37.5 %) took notice of polyhouse technology from other polyhouse farmers in both the zones taken together. For 25 per cent, it was the media and journals that introduced them to polyhouse cultivation. Twenty per cent of the farmers came to know about polyhouse technology from the extension activities conducted by government agencies such as ATMA (Agricultural Technology Management Agency) and SHM-K (State Horticulture Mission – Kerala). The role of private agencies in disseminating the technology is also worth mentioning as 17.5 per cent of the polyhouse farmers came to know about polyhouse cultivation technology from private agencies engaged in precision farming, protected cultivation, agricultural input supply etc.

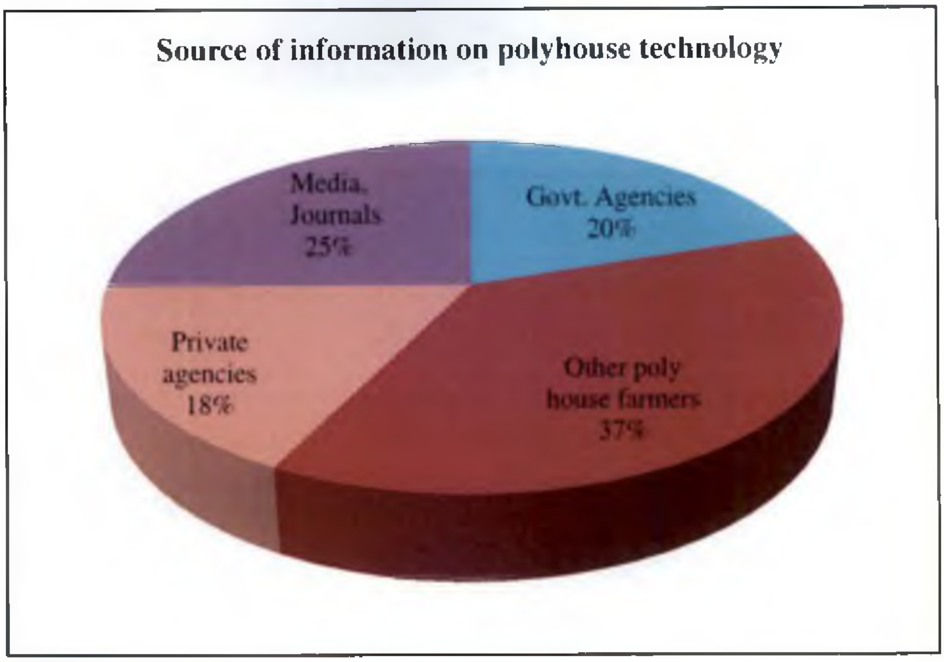

Fig. 10. Source of information on polyhouse technology

4.5.1b. Agencies involved in the construction of polyhouse

Polyhouse farmers of the study area assigned several agencies for the construction of their polyhouses. The agencies engaged in the construction and the numbers of farmers approaching each of them are given in Table 4.35. It was observed that 82.5 per cent of the total 40 polyhouses surveyed were constructed by private agencies. Polyhouses erected by the farmers themselves accounted for a mere 7.5 per cent. Ten per cent of the farmers approached other polyhouse farmers for the establishment of their polyhouse. Even though financial assistance is provided for the establishment of polyhouses, no government agency was found to involve in the construction of polyhouses in Kerala.

Table 4.35. Distribution of agencies involved in the establishment of polyhouse

Agency	No. of farmers
Govt. Agencies	0 (0)
Other polyhouse farmers	4 (10)
Private agencies	33 (82.5)
Own resources	3 (7.5)
Total	40 (100)

(Figures in parentheses indicate per cent to total)

During the study, it was revealed that the most challenging issue that a farmer faces in polyhouse cultivation is its higher establishment cost. When it is viewed in the context of agencies involved in the establishment, the role of private agencies in making the situation worse become more obvious. Majority of the farmers approached private agencies from Karnataka, Tamil Nadu and Kerala for polyhouse construction, and many among them had this bitter experience of being cheated by these agencies. Construction of polyhouses with inferior quality raw materials, lack of skilled labourers, breaking of contract in midway of work etc. are few tricks played by such agencies. Later farmers painstakingly have to themselves collect raw materials and arrange laboures to finish the work. Lack of any monitoring agencies at the government level worsens the condition. Apart from the financial aid no substantial technical help is seen extended from government agencies both in construction and cultivation. Government agencies such as Kerala Agro-industries Cooperation may take up polyhouse construction as one of their projects as it does not involve any sophisticated high-end technology or either they may engage in the supply of good quality raw materials for the construction.

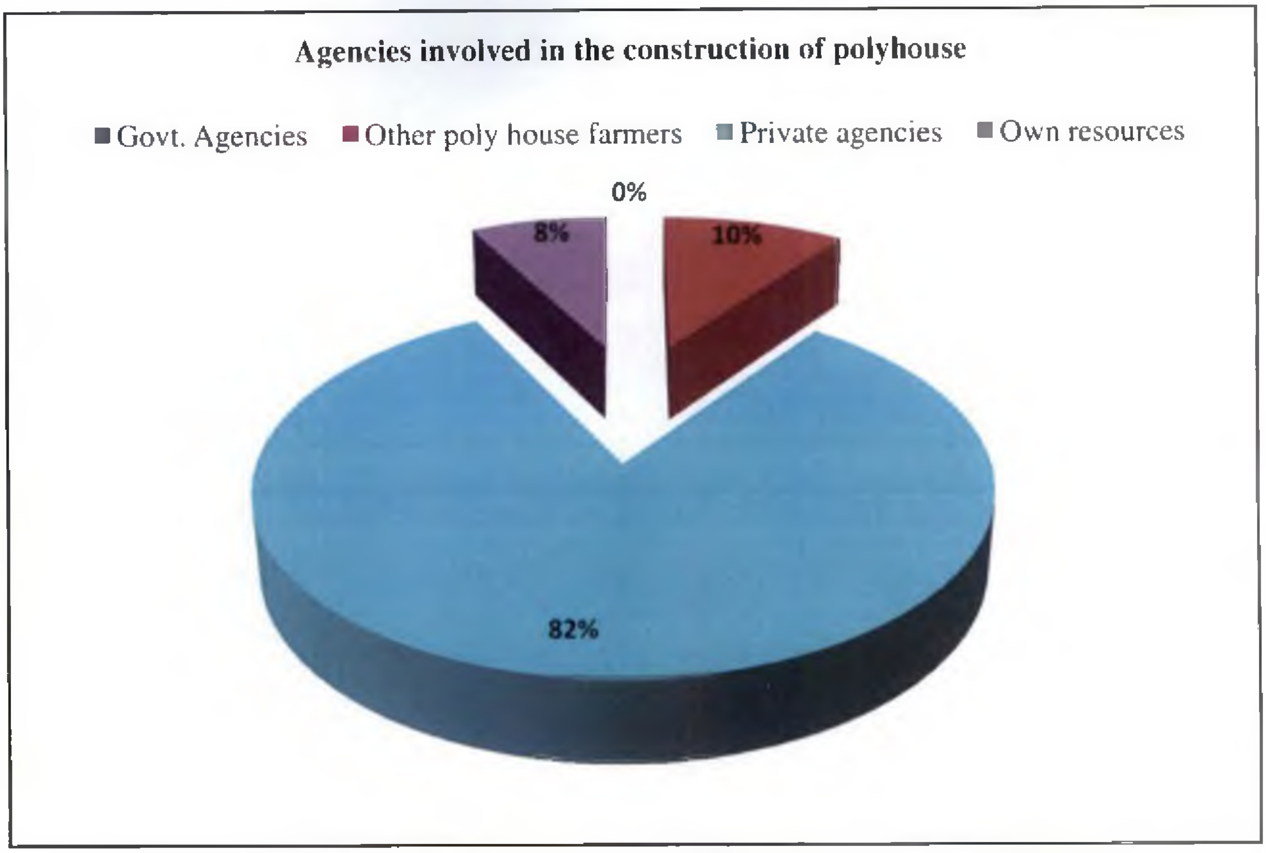

Fig. 11. Agencies involved in the construction of polyhouse

4.5.1c. Source of technical assistance for cultivation in polyhouse

Farmers receive technical assistance on polyhouse cultivation from different agencies such as Government agencies, other polyhouse farmers, private input agencies, scientists or experts, social media and internet. Table 4.36 shows the distribution of agencies providing technical assistance on polyhouse cultivation based on the number of farmers depend on each of them.

Table 4.36. Distribution of agencies providing technical assistance on polyhouse cultivation

Agency	No. of farmers adopting
Govt. Agencies	9 (22.5)
Other polyhouse farmers	8 (20)
Private input agencies	9 (22.5)
Scientists/ experts	9 (22.5)
Social media, internet	5 (12.5)
total	40 (100)

(Figures in parentheses indicate per cent to total)

It is evident from table 4.36 that the number of farmers consulting government agencies, private input agencies and scientists or experts in the field for technical assistance is the same (22.5 %). Twenty per cent of the farmers seek advice from other polyhouse farmers regarding polyhouse cultivation. Farmers browsing internet or seeking the help of social media groups for clearing doubts about polyhouse farming accounts for a notable 12.5 per cent of the total 40 polyhouse farmers surveyed.

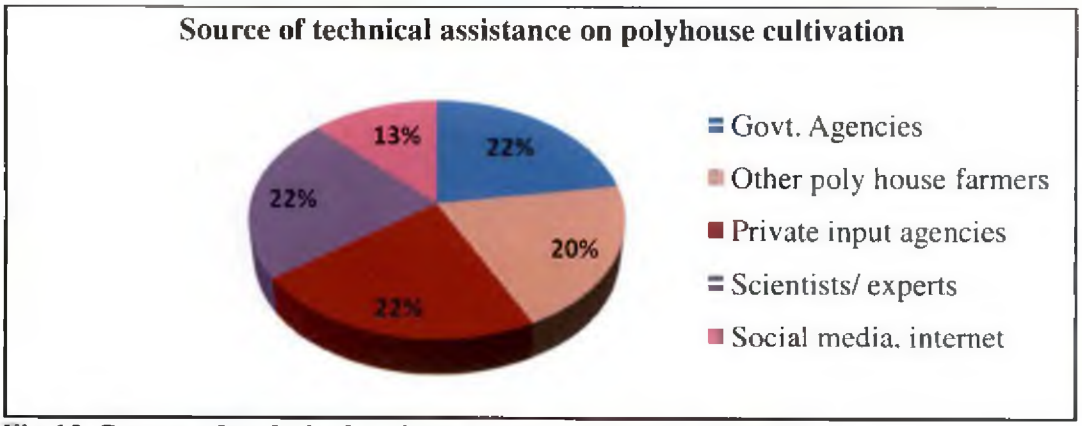

Fig.12. Source of technical assistance on polyhouse cultivation

Government agencies, private input agencies and scientists or experts in the field have equal role in providing technical help regarding polyhouse cultivation. Government agencies such as Krishi Bhavan, Krishi Vigyan Kendra, State Horticulture Mission- Kerala, ATMA etc. are engaged in supporting the farmers in polyhouse cultivation. Regular field visits or seminars are conducted by these agencies for assisting polyhouse farmers. The private input agencies trading polyhouse inputs also have a significant role in providing technical assistance to the farmers.

Summary and Conclusion

5. SUMMARY AND CONCLUSION

Polyhouse vegetable cultivation is gaining popularity in Kerala. Polyhouse cultivation especially in vegetable crops can be a viable option for year round production and availability of quality produce. There have been several studies which proved that it efficiently protects the plants from biotic and abiotic stresses. Besides, the yield levels are several times higher as well as the quality of produce is superior to open field cultivation of vegetables. The Government of Kerala and State Horticulture Mission have implemented several programmes to promote this technology in Kerala. The present study was conducted with the specific objectives to study the economics of production of vegetables under polyhouse condition in Kerala, to compare the profitability and resource use efficiency in polyhouse and open field cultivation, to enlist the problems faced in polyhouse cultivation and to study the factors which influence the decision making in adopting protected cultivation techniques.

Out of the five agro ecological zones of Kerala, central and high range zones were selected as the study location as these zones accounts for the maximum number of polyhouses in the state. Idukki and Wayanad districts of the high range zone and Ernakulam, Thrissur and Palakkad districts from the central zone were selected. From each zone, 20 polyhouse and 20 open field vegetable farmers were selected randomly, proportional to the total number of polyhouse farmers in the selected districts. Thus the total sample size comprises of 40 polyhouse vegetable farmers and 40 open field vegetable farmers and making up to total of 80. Data were collected by personal interview method using pre-tested structured interview schedule during September 2014- February 2015.

Variables such as socio-economic profile of respondents, crops and cultivation practices, general information on polyhouse cultivation, cost, returns, details on subsidies received, borrowing pattern, source of technology, extension linkages, problems and prospects of polyhouse cultivation etc. were chosen for the study based on the objectives, review of literature, pilot survey conducted and discussion with experts. Statistical tools like tabular analysis, percentages and averages, Fishers t test, Cochran–cox t test, Kendalls's coefficient of concordance, logistic regression, capital productivity analysis and production function analysis were used for analysis of data.

Analysis of socio-economic profile of the sample respondents indicated that, even though, male farmers are found prominent among both polyhouse and open field cultivation, a slightly higher proportion of female participation was observed in polyhouse cultivation. Farmers of age group, 49-59 years was identified more actively involved in agriculture than any other age group. A higher proportion of involvement of younger generation was observed in polyhouse cultivation than open field cultivation. The novel technology involved, reduced drudgery in farming, increased popularity in media etc. might have attracted the younger generations to take up polyhouse farming than open field cultivation. The analysis on years of experience in farming also strengthens the observation, because majority of the polyhouse farmers are having an experience of 20 years or below in farming. When the educational level of farmers was analysed it was strikingly observed that the polyhouse farming and the educational level of farmers are positively related. Majority of farmers who have taken up polyhouse cultivation are graduates and a good proportion are having higher secondary or above educational qualifications; where as a greater part of the open field farmers are with primary schooling or below. The occupational profile of farmers revealed that agriculture is the sole occupation for a larger number of polyhouse farmers than open field farmers. A further inquiry into their occupation before and after the establishment of polyhouse or start of vegetable cultivation revealed that the number of respondents who have shifted from their earlier occupation was significantly high among polyhouse farmers as compared to open field farmers. It was also striking that all of the respondents among polyhouse farmers who showed a shift in occupation have converted into full time farmers leaving their earlier occupation.

Though a greater part of polyhouse farmers have marked farming as their sole occupation, majority of them are receiving family income between Rs. 1-2 lakh (27.5 %) and above Rs. 4 lakh (27.5 %) annually. This implies that for most of them, farming is not the only source of family income; whereas, for majority of open field farmers, farming is the family's sole livelihood and their mean annual family income falls between Rs. 0.75 – 1 lakh (42.5%). Majority of the farmers surveyed (polyhouse – 42.5%, open field – 67.5 %) falls in the marginal farmer category. It was also noteworthy that, when 7.5 per cent of polyhouse farmers grouped as large, there are no large farmers among open field vegetable farmers.

When the salient features of polyhouse cultivation in the study area were looked into, it was observed that the design type and other technical specifications of polyhouses showed no much difference in both the zones. The predominant type was naturally ventilated saw-tooth type with side and roof ventilation. The number of polyhouses installed over years implied that there is an increasing trend in adoption of this technology over time both in central as well as high range zone. The study revealed that a good number of the polyhouses in both central and high range zone are with an average area of $400m^2$. When the crops cultivated in polyhouses in the study area was examined, it was observed that cowpea and salad cucumber are the two prominent crops widely cultivated in polyhouses in the study area. Nineteen out of 20 farmers in central zone and six out of 20 farmers in high range zone are cultivating salad cucumber. Sixteen out of 20 farmers in central zone and 15 out of 20 farmers in high range zone are cultivating cowpea in polyhouses.

Since salad cucumber and cowpea are the most commonly cultivated crops in polyhouses in the study area, the economic feasibility analysis was carried out for production of salad cucumber and cowpea, and 400m^2 was assumed as the standard area of cultivation as majority of the farmers in the study area owned polyhouses of area 400m^2. Crop sequence with cowpea – salad cucumber – cowpea was observed as the most common one in polyhouses; hence an attempt was also made to determine the economic feasibility of this crop sequence employing the same methods as that for sole crop of salad cucumber and cowpea. Kerala state government and central government through SHM have implemented several programmes to promote polyhouse cultivation in the state. Farmers are receiving sizeable amount as subsidy for the establishment of polyhouse. Hence, the economic feasibility analysis has also been worked out considering the subsidy factor. Comparative studies were done for cowpea alone, as farmers cultivating salad cucumber in open field were not available.

Polyhouse cultivation of vegetables involves three types of costs viz, fixed cost, annual variable cost and seasonal variable cost. Fixed costs include the cost of establishment of polyhouse and it is the major component of cost of production of polyhouse vegetables. It requires Rs.4,54,330 for constructing a polyhouse of 400m^2 area (Rs. 1,136 / m^2). The costs incurred on inputs which last for one year are grouped as annual variable cost. The average annual variable cost for cultivation of salad cucumber in polyhouse was estimated to be Rs. 3669 per 400 m^2 and that of cowpea was Rs. 1630 and cowpea – salad cucumber – cowpea sequence was Rs. 3777. Seasonal variable cost accounts for the cost of variable inputs that are used during each cropping season. The average seasonal variable cost for salad cucumber was worked out to be Rs. 40609 per 400m^2, and that for cowpea was Rs. 25998. The higher cost for salad cucumber was due to notably high cost on seeds, plant protection chemicals, bio control agents and higher involvement of family labour as indicated by a high value of imputed family labour than that on cowpea. It is also noteworthy that cost on machine labour, packing materials and post harvest handling was not incurred in the cultivation of cowpea. In both the crops, the breakup of cost indicated that highest cost was incurred for labour followed by manures, fertilizers, growth promoters and soil ameliorants.

The economic feasibility analysis of polyhouse production estimated a Payback period of 3.2 years for sole cultivation of salad cucumber, which was 5.2 years in the case of the crop sequence; where as it was estimated to an unfavorable 8.4 years in sole cultivation of cowpea. Net Present Value was positive in all the cases except sole crop of cowpea with a less than zero NPV at 12 per cent discount rate. Benefit Cost Ratio was seen well above unity in sole crop of salad cucumber and the crop sequence cowpea – salad cucumber – cowpea with values varying from 1.5 for salad cucumber and 1.1 for the crop sequence; but, sole crop of cowpea showed a less than one BCR. The Internal Rate of Returns was sufficiently high at 42 per cent per annum for the cultivation of salad cucumber. It was 19 per cent per annum for the crop sequence and an undesirable two per cent for sole crop of cowpea. Hence, it was concluded that sole cultivation of salad cucumber and crop sequence involving two crops of cowpea and one crop of salad cucumber are economically feasible and profitable in polyhouses of Kerala; while the cultivation of cowpea for the entire three seasons in polyhouses was not found to be an economically viable option.

A similar analysis has also been conducted to know whether the subsidy received by polyhouse farmers will improve the economic viability of cultivation of these crops. After accounting for the subsidy factor, all the indicators showed improvement in all the cultivation situations. The payback period has reduced from 3.2 years to 1.6 years in case of sole crop of salad cucumber. It is now 2.5 years in case of the crop sequence from an earlier 5.2 years. BC ratio has also been improved significantly. NPV has multiplied to several manifolds than the earlier situation. Change in IRR also shows an improved economic viability than the earlier situation. A remarkable change has been observed in the cultivation of cowpea. The subsidy provided could significantly improve the situation. Payback period has reduced from 8.4 years to 3.5 years. BC ratio has now become more than unity from an earlier 0.83. All the parameters indicate that the subsidy factor could all over transform the earlier impractical situation into a highly profitable and feasible one.

A comparison has been attempted to examine the profitability of cowpea cultivation in polyhouse and open field conditions. Even though the return is lower in open field cowpea cultivation, all the feasibility parameters indicate that open field cultivation is economically viable over polyhouse cultivation. The Payback period was 4.2 years in open field cultivation while it was an unreasonable 8.4 years in polyhouse cultivation. Benefit Cost Ratio was seen above unity in open field cowpea cultivation whereas it was just 0.83 in polyhouse cultivation. Net Present Value was positive in open field cultivation as against a negative NPV in polyhouse cultivation. Internal Rate of Return in open field cultivation also indicates that it is an economically feasible venture. Returns to scale was also found higher in open field cowpea cultivation than in polyhouse.

When the resource use of cowpea production in polyhouse and open field was compared, production and net returns per unit area was found significantly high in cowpea cultivated in polyhouse. Nevertheless, the significantly higher value of seeds, quantity of soil ameliorants, manures, plant protection chemicals and bio control agents applied adds to the cost of production in polyhouse.

The resource use efficiency of production was estimated using Cobb-Douglas production function. The best production function selected for salad cucumber production in polyhouse could explain 59 per cent of the variations in the net returns per m^2. Value of seeds, value of hired labour, quantity of soil ameliorants and fertilizers applied were obtained as the significant variables. Similarly, the best production function selected for cowpea in polyhouse could explain 57 per cent of variations in the net returns per m^2. Value of hired labour and quantity of manures applied were the significant variables. Ninety four per cent of the variations in net returns per m^2 could be explained by the production function selected for cowpea in open field. The significant variables obtained in the production function were: value of seeds, quantity of manures, fertilizers, plant protection chemicals and bio control agents applied. The results revealed that there is an increasing Returns to Scale in the production of salad cucumber in polyhouse (1.6), cowpea in polyhouse (1.57) and cowpea in open field (2.01) conditions.

The efficiency ratio of vegetable cultivation in polyhouse and open field was estimated to further ascertain the resource use efficiency in all the cultivation situations. The data revealed that in the two polyhouse cultivation situations (salad cucumber and cowpea) resources are not efficiently utilized. When judged against the economic efficiency of the same inputs (fertilizers and growth promoters) used in polyhouse cultivation of cowpea, the economic efficiency in open field cultivation is seem advantageous.

High initial investment involved, farmer's lack of technical knowledge, non availability of technical experts in local area, non availability of extra premium for produce, non availability of good quality materials for the establishment of polyhouse, inaccessible seed prices etc. were identified as the major constraints faced by polyhouse farmers of both high range and central zone who showed a high level of agreement to list the major challenges of polyhouse cultivation. The important benefits of polyhouse farming as perceived by the farmers included the possibility of growing and consuming safe vegetables, possibility of growing off season vegetables, better quality produce, higher yield and income obtained from polyhouse cultivation etc.

Conclusion

Polyhouse cultivation has emerged as a potential technology for enhanced production combating biotic and abiotic stresses in crop production. Though polyhouse cultivation is a promising new technology, its suitability in Kerala conditions has to be studied extensively. Even though, institutional credit and subsidy schemes are well implemented to promote the technology, farmers are still in dilemma when it comes to cultivation aspects, for most of them it is a new venture. Though there is an Ad hoc recommendation put forth by Kerala Agricultral University on polyhouse cultivation of crops, it was more or less unpopular among the farmers. Returns to scale in polyhouse cultivation signifies its economic feasibility in large scale cultivation. For a state like Kerala, where the per capita land holding is very less (0.12 Ha), cost effective polyhouses and suitable crop production technologies are to be evolved. Research efforts aimed at reducing the establishment cost of polyhouse should be initiated. As the materials used for construction of polyhouses are plastic based, the long run environmental impacts of these materials may be studied. A major impediment in the adoption of this technology was perceived as the lack of sufficient qualified technicians for construction and maintenance of polyhouses. Organizing labour banks and imparting skilled training to youth on polyhouse technology and scientific cultivation practices may be a welcoming approach in efficient polyhouse technology dissemination.

Policy suggestions and future line of work

Based on the results of the study, observations in the field and discussion with officials of the agriculture department, the following courses of action in polyhouse cultivation technology in Kerala is suggested

- Designing and developing location specific polyhouse structures, crop planning and crop sequencing
- Research oriented towards developing cost effective polyhouse technology
- Research for development of crops and crop varieties suited for polyhouse cultivation
- Evolving value chains and efficient post harvest handling techniques to absorb the marketable surplus generated from polyhouse cultivation.

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Appendices

APPENDICES

Appendix. I: Procedure for stepwise regression and backward elimination

Cobb- Douglas production function was fitted to find out the resource use efficiency of cowpea cultivation in polyhouse, salad cucumber cultivation in polyhouse and cowpea in open field. The best model was identified using backward elimination method. The result of stepwise regression and backward elimination are presented in the Table I, Table III, and Table V. for all the cultivation situations.

i) Cowpea cultivation in polyhouse

Table I. Cobb – Douglas production function for cowpea cultivation in polyhouse

Sl. No	Cobb – Douglas production function	R^2	Adjusted R^2
1	$Y=1.055-0.43X_1+1.08X_2+.11X_3-0.47X_4+0.11X_5+0.37X_6+0.83X_7-0.03X_8$	0.73	0.41
2	$Y=1.159+1.06X_2^{*}+0.11X_3-0.47X_4+0.12X_5+0.37X_6+0.85X_7-0.024X_8$	0.73	0.49
3	$Y=0.99+1.11X_2^{*}+0.10X_3-0.46X_4+0.12X_5+0.36X_6+0.08X_7$	0.72	0.54*
4	**$Y=1.39+0.98X_2^{**}+0.08X_3-0.36X_4+0.42X_6^{**}+0.12X_7$**	**0.72**	**0.57****
5	$Y= 0.33+1.17X_2^{**}+0.09X_3-0.47X_4^{*}$	0.64	0.50*

* - Significant at 5% level
** - Significant at 1% level

It could be seen that the value of adjusted coefficients of determination of first production function was 0.41 using all the 8 regressors. But, none of the regression coefficients were significant. Using backward elimination process, the least contributing variable was removed and again a Cobb-Douglas production function was fitted. The adjusted R^2 could be improved to a value of 0.49. This procedure was repeated and ultimately, the best model for prediction was identified based on maximum value of adjusted R^2 and checking the absence of multicollinearity among regressors using the VIF criterion. The fourth model in the Table I was selected as the best model for prediction.

Table II. Collinearity statistics of the regressors in the selected model

Variable	VIF
Value of hired labour/m^2 (X_2)	2.921
Value of family labour/m^2 (X_3)	2.262
Expenditure on transportation/m^2 (X_4)	4.175
Quantity of manures applied/m^2 (X_6)	3.824
Quantity of fertilizers applied/m^2 (X_7)	2.351

ii) Salad cucumber cultivation in polyhouse

Table III. Cobb – Douglas production function for salad cucumber cultivation in polyhouse

Sl. No	Cobb – Douglas production function	R^2	Adjusted R^2
1	$Y = 5.19-0.56X_1+0.43X_2+0.22X_3+0.89X_4+0.25X_5+0.12X_6-0.44X_7-0.17X_8$	0.81	0.42
2	$Y = 5.5-0.56X_1+0.41X_2{*}+0.16X_3+0.91X_4+0.27X_5{*}-0.41X_7-0.12X_8$	0.80	0.52
3	$Y = 5.1-0.25X_1{*}+0.39X_2{*}+0.19X_3+0.89X_4+0.26X_5{*}-0.36X_7$	0.79	0.58
4	$\mathbf{Y = 5.9-0.46X_1{*}+0.29X_2{*}+0.72X_4+0.26X_5{**}-0.27X_7{*}}$	**0.76**	**0.59***
5	$Y = 5.65-0.25X_1+0.17X_2{*}+0.21X_5{*}-0.17X_7$	0.64	0.46
6	$Y = 5.10-0.15X_2{*}+2.12X_5{*}-0.16X_7$	0.56	0.39
7	$Y = 5.63+0.91X_2+0.206X_5{*}$	0.44	0.32*

* - Significant at 5% level

** - Significant at 1% level

It is observed that the value of adjusted coefficients of determination of first production function was 0.42 using all the 8 regressors. But, none of the regression coefficients were significant. Using backward elimination process, the least contributing variable was removed and again a Cobb-Douglas production function was fitted. The adjusted R^2 could be improved to a value of 0.52. This procedure was repeated and ultimately, the best model for prediction was identified based on maximum value of adjusted R^2 and checking the absence of multicollinearity among regressors using the VIF criterion. The fourth model in the Table III was selected as the best model for prediction.

Table IV. Collinearity statistics of the regressors in the selected model

Variable	VIF
Value of seed/m^2 (X_1)	1.603
Value of hired labour/m^2 (X_2)	5.276
Expenditure on transportation/m^2 (X_4)	3.210
Quantity of soil ameliorants applied/m^2 (X_5)	1.189
Quantity of fertilizers applied/m^2 (X_7)	2.353

iii) Cowpea cultivation in open field

Table V. Cobb – Douglas production function for cowpea cultivation in open field

Sl. No	Cobb – Douglas production function	R^2	Adjusted R^2
1	$Y = 3.611+0.31X_1{**}+0.03X_2{*}-0.43X_3+0.73X_4{**}+0.50X_5-1.40X_6{**}-0.06X_7+2.36X_8{**}$	0.90	0.91**
2	$Y= 4.25+0.61X_1{**}-0.01X_2-0.49X_6{**}+0.09X_7+0.66X_8{**}$	0.96	0.93**
3	**$Y = 4.23+0.60X_1{**}-0.49X_6{**}+0.08X_7{*}+0.66X_8{**}$**	**0.96**	**0.94****

* - Significant at 5% level
** - Significant at 1% level

The value of adjusted coefficients of determination of first production function was 0.99 using all the 8 regressors. But, a few of the regression coefficients were non-significant. Using backward elimination process, the least contributing variable was removed and again a Cobb-Douglas production function was fitted. The adjusted R^2 could be improved to a value of 0.93. This procedure was repeated and ultimately, the best model for prediction was identified based on maximum value of adjusted R^2 and checking the absence of multicollinearity among regressors using the VIF criterion. The third model in the Table V. was selected as the best model for prediction.

Table VI. Collinearity statistics of the regressors in the selected model

Variable	VIF
Value of seed/m2 (X1)	2.504
Quantity of manures applied/m2 (X6)	5.206
Quantity of fertilizers applied/m2 (X7)	3.308
Quantity of PPC & Bio-control agents applied/m2 (X8)	8.111

Appendix II: Cost of open field cultivation of cowpea

Sl. No.	Item	Cost (Rs./ 400m^2)
I	**Fixed cost**	20062
II	**Annual variable cost**	
1.	Propping and trailing materials	652
III	**Seasonal variable cost**	
1.	Seed	83
2.	Hired human labour	5839
3.	Manures	1667
4.	Fertilizers, growth promoters	597
5.	PPC and bio control agents	452
6.	Soil ameliorants	170
7.	Transportation	171
8.	Family labour (valued at prevailing wage rate)	6000
	Total	35693

Abstract

ECONOMIC FEASIBILITY OF VEGETABLE PRODUCTION UNDER POLYHOUSE CULTIVATION

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ABSTRACT OF THE THESIS

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ABSTRACT

Polyhouse cultivation of vegetables is emerging as a specialized production technology to overcome biotic and abiotic stresses and to break the seasonal barrier to production. It also ensures round the year production of high value vegetables especially, during off-season. Recent statistics show that about 115 countries in the world are into polyhouse vegetable production. The area under polyhouse vegetable cultivation in India is around 2000 hectares. Since polyhouse production is a capital-intensive technology requiring substantial initial investment, cost is the major issue in sustaining this technology.

The present study was undertaken to assess the economic feasibility of polyhouse cultivation of vegetables in Kerala. The profitability and resource use efficiency of vegetable production in polyhouse and open field situations and the factors which influence the decision making of farmers with regard to adoption of precision farming was also found. The major challenges faced by polyhouse farmers of Kerala were also enlisted.

Out of the five agro ecological zones of Kerala, central and high range zones were selected as the study area, as these zones accounted for the maximum number of polyhouses in the state. In the high range zone both Idukki and Wayanad districts and from the central zone, the districts of Ernakulam, Thrissur and Palakkad were selected. Twenty polyhouse and 20 open field vegetable farmers selected randomly from each zone formed the respondents of the study. The number of respondents in a district was fixed proportional to the total number of farmers in the district concerned. Thus the total sample size comprises of 40 polyhouse vegetable farmers and 40 open field vegetable farmers. Data were collected by personal interview method using pre-tested structured interview schedules.

The survey indicated that majority of the farmers owned polyhouses of area $400m^2$. Salad cucumber and cowpea were the commonly cultivated polyhouse

crops in the study area. Hence, economic analyses were conducted for the crops salad cucumber and cowpea and for a polyhouse of standard size $400m^2$. Comparative studies were done for cowpea alone, as farmers cultivating salad cucumber in open field were not available.

Economic feasibility of vegetable production analyzed using Capital Productivity Analysis revealed that production of salad cucumber in polyhouse and cowpea in open field is highly feasible and profitable. Production of cowpea in polyhouse indicated unfavourable Benefit Cost Ratio, negative Net Present Value and low Internal Rate of Returns. When the resource use of cowpea production in polyhouse and open field was compared, production and net returns per unit area was found significantly high in cowpea cultivated in polyhouse. Nevertheless, the significantly higher value of seeds, quantity of soil ameliorants, manures, and bio control agents applied contributed to higher cost of cultivation along with the huge initial investment in polyhouse.

The resource use efficiency of production was estimated using Cobb-Douglas production function. The best fit model for salad cucumber production in polyhouse could explain 59 per cent of the variations in the net returns per m^2. Value of seeds, value of hired labour, quantity of soil ameliorants and fertilizers applied were the significant variables. The best model for cowpea in polyhouse could explain 57 per cent of variations in the net returns per m^2. Value of hired labour and quantity of manures applied were the significant variables. Ninety four per cent of the variations in net returns per m^2 could be explained by the selected functional model for cowpea production in the open field. The significant variables obtained were value of seeds, quantity of manures, fertilizers, plant protection chemicals and bio control agents applied. Increasing Returns to Scale was observed in the production of salad cucumber in polyhouse (1.60), cowpea in polyhouse (1.57) and cowpea in open field (2.01) conditions.

The efficiency ratio of vegetable cultivation in polyhouse and open field estimated revealed that resources are not efficiently utilized in polyhouse cultivation of vegetables to the maximum economic advantage. When judged against the economic efficiency of the same inputs (fertilizers and growth promoters) used in polyhouse cultivation of cowpea, the economic efficiency in open field cultivation is seem advantageous.

There was high level of agreement between the polyhouse farmers of the central and high range zone in enlisting the high initial investment involved, followed by farmer's lack of technical knowledge, non availability of technical experts in local area and non availability of premium price for produce as the major challenges faced. The major benefits of polyhouse farming as perceived by the respondents included the possibility of growing and consuming safe vegetables, possibility of growing off season vegetables, better quality produce, higher yield and income obtained from polyhouse cultivation.

The factors leading to a decision by the farmers towards shifting to polyhouse cultivation from open field cultivation subject to the extreme conditions of weather were found to be family income, size of land holding and education of the farmer, with odds ratios of 0.74, 0.72 and 0.68 respectively.

Though polyhouse cultivation is a promising new technology, its suitability in Kerala conditions has to be studied extensively. Even though, institutional credit and subsidy schemes are well implemented to promote the technology, farmers are still in dilemma when it comes to cultivation aspects, for most of them it is a new venture. Higher Returns to Scale in polyhouse signifies its economic potential in large scale cultivation. Research efforts aimed at reducing the establishment cost of polyhouse should be initiated. The extension linkage has to be strengthened to aid the polyhouse farmers in selection of crops, cultivation, post harvest handling and marketing of produce.