COMPARATIVE EVALUATION OF NATURALLY VENTILATED POLYHOUSE AND RAINSHELTER ON THE PERFORMANCE OF COWPEA

By

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Thesis

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DECLARATION

I hereby declare that this thesis entitled **"Comparative Evaluation of Naturally Ventilated Polyhouse and Rainshelter on the Performance of Cowpea"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me for any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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SYMBOLS AND ABBREVIATIONS

%	Percentage
°C	Degree Celsius
µm	Micrometer
ASM	Available soil moisture
B:C	Benefit Cost ratio
cm	Centimeter
DAP	Days After Planting
DI	Drip Irrigation
dS/m	deci Siemens per meter
E	East
Ep	Pan Coefficient
ET	Evapotranspiration
FC	Field Capacity
g/kg	Gram per Kilogram
GI	Galvanized Iron
GM	Genetically modified
GPS	Global Positioning System
ha	Hectare
IARI	Indian Agriculture Research Institute
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	Kilogram
Kg ha^{-1}	Kilogram per Hectare

kg/m^2	Kilogram per square meter
Kpa	Kilopascal
LDPE	Low Density Polyethylene
lph	Litre per hour
m	Meter
m^2	Square meter
m^2/year	Meter Square per year
MAP	Monoammonium Phosphate
me/L	mill equivalent per Litre
mg/L	Milligram per Litre
mm	Millimeter
N	North
NAA	Napthyl Acetic Acid
NPK	Nitrogen, Phosphorous, Potassium
PE	Pan Evaporation
PFDC	Precision Farming Development Centre
pH	Negative Logarithm of Hydrgen Ion
PVC	Poly Vinyl Chloride
q/ha	Quintal per Hectare
SLW	Specific Leaf Weight
Sq.km	Square Kilometer
T	Treatment
t/ha	Tonnes per Hectare

UV	Ultra Violet
UVA	Ultra Violet A
VPD	Vapour Pressure Deficit
Wm^{-2}	Watt per square meter

CHAPTER 1

INTRODUCTION

Kerala is a land of diversities with a high population density of around 860/sq.km, compared to the National density of 364/sq.km. The percentage share of state income from agriculture is only 20% and this income is generated from marginal holdings of less than one hectare size with the average size being 0.18 ha. With the improvement in the living conditions and food habits of Keralites, the necessity for increasing the vegetable production from these small land holdings becomes essential.

Kerala enjoys a warm humid tropical climate and the long term rainfall of the state is 2817 $\pm$ 406 mm. June and July are the rainiest months while summer months receive least rainfall. The season wise rainfall contribution over Kerala indicates that 68 % of annual rainfall is received during the monsoon followed by post monsoon (16%). A perusal of the vegetable production in the state reveals that majority of the vegetable production within the state is contributed by summer vegetables cultivated in rice fallows and river beds. During rainy season, in addition to tuber crops only few vegetables like cowpea, okra, bitter gourd and brinjal are grown in the State. High rainfall and high humidity limit the vegetable production due to many biotic stresses. Moreover untimely and erratic rainfall also lowers vegetable production as well as seed production. Kerala depends on neighbouring states for its vegetable requirements during the period.

Precision farming and protected cultivation technology becomes relevant in this context. These technologies provide the best way to increase the productivity and quality of vegetables. Precision farming refers to the precise application of inputs to ensure optimum crop production. The intent of precision farming is to match agricultural inputs and practices as per crop and agro-climatic conditions to improve the accuracy of their applications. It is generally defined as information and technology based farm management system to identify, analyse and manage variability within fields for optimum profitability, sustainability and protection of the land resources. In this mode of farming, new information technologies can be used to make better decisions about many aspects of crop production. Precision farming helps many farmers worldwide to maximize the effectiveness of crop inputs. Precision agriculture is often referred to as GPS (Global Positioning System) agriculture or variable rate farming. The potential of precision farming for economical and environmental benefits could be visualized through reduced use of water, fertilizers, herbicides and pesticides besides the farm equipments. Instead of managing an entire field based upon some hypothetical average condition, which may not exist anywhere in the field, precision farming approach recognizes site-specific differences within field and adjusts management actions accordingly. Farmers usually are aware that their fields have variable yields across the landscape. These variations can be traced to management practices, soil practices and environmental characteristics. Soil characteristics that affect yields include texture, structure, moisture, organic matter, nutrient status and landscape position. Environmental characteristics include weather, weeds, insects and diseases.

Protected cultivation can be defined as the cropping techniques where the microclimate surrounding the plant body is controlled partially or fully as per the requirement of plant species grown during their period of growth. With the diverse agro-climatic condition prevailing in our state this technology can be utilized for year round cultivation of high quality vegetables, for raising healthy seedlings, production of off-season vegetables and hybrid seed production of high value vegetables. Two important aspects coming under protected cultivation are polyhouse and rainshelter.

A polyhouse is a framed structure covered with transparent poly film, which protects plants from wind, precipitation, excess solar radiation, temperature extremes, pests and diseases. It is a controlled environment which allows optimum growth. The sunlight entering into a polyhouse is absorbed by the crop, floor and other objects in the polyhouse. These objects, in turn, emit long wave thermal radiation for which the covering materials have low transparency. As a result, the solar energy is trapped in the polyhouse raising its temperature. This phenomenon is generally known as green house effect and is the basic principle behind polyhouse cultivation. Polyhouse cultivation is known as isolated, intensive and protective cultivation, which results in a quality crop produce, which has a high demand in local and overseas market. Normally the people can recover the investment within 2 ½ - 3 years. Polyhouse farming also promises to extent the harvest life of vegetables like cowpea by one to one-and-a-half months. Capsicum, salad cucumber, tomatoes, bitter gourds and cowpeas have been great success in the polyhouses in Kerala.

The specific benefits of polyhouse cultivation are:

- Throughout the year, four to five corps can be grown to meet the market demands due to the availability of required environmental conditions.
- High value and high quality crops could be grown for export markets.
- Income from small land holdings could be increased.
- Efficient use of inputs such as water, nutrient, seed, plant protection chemicals etc.
- Percentage of germination of seeds and plant propagation is high in polyhouses.
- Minimum labour is required.

Polyhouse farming process requires expertise in three areas such as construction of the structure, cultivation techniques and marketing. It entails construction of a metal structure covered by polythene. Parameters such as humidity, soil nutrients and temperature in the polyhouse are controlled to ensure timely and abundant yields.

If the local farmers were able to take up vegetable cultivation during the off season, they can achieve better income. Protected cultivation helps the farmers to grow vegetables year-round, but a hi-tech green house with sophisticated environmental control cannot be recommended to farmers with limited resources. Here comes the application of low cost technology of protected cultivation named

Rainshelter. Rainshelter is a naturally ventilated low cost greenhouse which facilitates year round production of high value crops like tomato, capsicum, cabbage, cut flowers etc. and also suitable for raising vegetable seedlings. This technology is acceptable to small scale and marginal farmers. The frame work can be made of either G.I pipes or wooden or bamboo poles or even with arecanut splits. Cladding (roofing) is provided with transparent UV stabilized low density polyethylene film of 200 micron thickness.

Since there are different arguments regarding the adaptability and advantages of polyhouse, rainshelter and open field precision farming, a scientific study in this regard is necessary. In the present study cowpea is selected for comparing the growth and yield performance under polyhouse rain shelter and open field conditions. Yard long bean (*Vigna unguiculata*)**,** known as 'Achinga Payar' in Malayalam is an important vegetable of Kerala, next to bitter gourd in coverage and preference. It is a vigorous climbing crop and grows up to a height of three to four meters producing very long, slender and succulent pods which may be white, light green, dark green or brownish red in colour. The pods are rich in protein (28 %), iron, calcium, phosphorus, vitamin A, vitamin C and dietary fibre. It also has the ability to fix atmospheric nitrogen through its root nodules and it grows well in poor soils with more than 85% sand and with less than 0.2% organic matter and low levels of phosphorus. Cowpea can be grown throughout the year under Kerala conditions and can be grown as a floor crop in coconut gardens and as an intercrop in tapioca during May-Sept. It can be grown as a pure crop in single-crop and double-crop rice fallows during rabi and summer seasons. Cowpea can be grown in homestead gardens throughout the year and in kole lands during summer where rice crop cannot be raised due to water scarcity. In Kerala it is also used to cultivate inside polyhouse and rainshelter and because of the climbing nature, the plants are trailed over pandal or trellis.

The present study is proposed to compare the performance of cowpea grown under polyhouse and rainshelter in relation to open field cultivation with the following specific objectives:

- To compare the yield of cowpea grown under polyhouse, rain shelter and open field.
- To work out the Benefit Cost (B: C) ratio for the polyhouse and rainshelter for cowpea cultivation.

CHAPTER 2

REVIEW OF LITERATURE

This chapter deals with comprehensive review of the research work done by various researchers related to the present study. The literature pertaining to the performance of vegetables under polyhouse and rain shelter in relation to open field conditions is reviewed here.

2.1 PERFORMANCE OF VEGETABLE CROPS UNDER POLYHOUSE

Backer (1989) reported that sweet pepper grown with alternative high and low humidity during day and night (vapour pressure deficit range 0.30 to 0.75 Kpa) under greenhouse gave more fruit set (16.70 %) and more number of fruits (10.9 per plant) as compared to continuous high (0.75 Kpa) or low humidity. There was no significant effect on fruit shape and maturity.

Under polyethylene greenhouse condition, maximum yield of ripe tomato fruits (8.6 kg/ m^2) and total yield (9.4 kg/ m^2) was obtained as compared to open conditions (6.6 kg/ m^2 and 7.35 kg/ m^2, respectively) (Ohigbu and Harris, 1989).

Maximum yield of 507 q/ha were obtained in tomato and French bean respectively inside the greenhouse as compared to no yields under open conditions because of severe frost during winter in hilly regions of Uttar Pradesh. Further, low incidence of early blight and septorial leaf spot was observed in tomato and angular leaf spot in french bean was noticed under greenhouse condition (Bhatnagar *et al*., 1990).

More *et al.* (1990) reported that cucumber variety ‘Poinset’ gave a yield of 1.70 kg/ plant under polyhouse as compared to fewer yields in open conditions, during winter months under North Indian conditions due to low temperatures.

Gomez and Hernandez (1994) conducted a comparative study among capsicum cultivars planted on 2nd June. They were assessed for flowering dates, beginning of cropping and full cropping, yield in each of four harvests and total yield, and percentage of fruits in four different weight groups. Cultivars Vidi and

Elisa gave the higher total yields (30, 030 and 30, 468 kg/ha, respectively), almost twice as high as for cultivar Fiuco (16,268 kg/ha) in the first harvest; in this harvest Elisa and Fiuco yielded 6738 and 3417 kg/ha, respectively.

Rai *et al.* (1995) studied shelf life of capsicum grown under protected and open conditions. Six hybrids along with one open pollinated variety were grown in polyhouse and open conditions for studying their shelf life. The shelf life of capsicum fruits harvested from polyhouse was more than that of fruits harvested from open conditions. The maximum shelf life of sixteen days was recorded in Arun F1 growing in polyhouse, while it was only ten days in fruits produced in open condition.

Ganesan (1999) conducted a study to define the effect of changes in microclimate produced by poly greenhouse conditions on plant growth characteristics and fruit yield of tomato. The UV stabilized plastic film covered greenhouse recorded higher day temperature than the open environment but relative humidity at 8 AM was lower inside the greenhouse except from May to August. The light intensity inside the greenhouse was lower than in the open field. Height of the plant, number of nodes, internodal length, total dry matter production and average fruit weight increased under greenhouse conditions as compared to open field condition. The fruit yield inside the greenhouse was nearly two times more than in the open field condition.

Von (1999) reported that the main advantage with greenhouse farming is that the production can be got throughout the year, which is not possible in the open field farming due to heavy rainfall and wind, especially in tropical regions

Nazzareno *et al.* (2002) evaluated GM parthenocarpic eggplants in three field trials. Two greenhouse spring trials have shown that these plants out yielded the corresponding untransformed genotypes, while a summer trial has shown that improved fruit productivity in GM eggplants can also be achieved in open field cultivation.

Santos *et al.* (2009) compared the effects of the protected cultivation and open field on growth of *Lactuca sativa* plants through morphological parameters. The morphological parameters evaluated were fresh and dry leaf matter, fresh and dry stem matter, fresh and dry plant matter, leaf number, leaf area and absolute growth rate. The leaf fresh matter suffers significant effect, which for the treatment under protected cultivation was higher that the treatment carried out with plants in open field in all evaluated points. The plant dry matter production on 28th day after transplanting increased by 56.56 %, when compared with open field condition. The leaf number shown significant difference on the 14th and 21th day after transplanting, in which the treatment under protected cultivation resulted in an increase of 64.2% on 14th day after the transplanting, when compared with open field condition.

Parvej *et al.* (2010) compared the phenological development and production potentials of two tomato varieties viz. BARI Tomato-3 and Ratan under polyhouse and open field conditions. Photosynthetically active radiation inside the polyhouse was reduced by about 40 % compared to the outside while air and soil temperatures always remained higher. From December to February the mid day air temperature under polyhouse and open field varied from 31.8 to 39.1 ºC and 23.3 to 31.1 ºC respectively, indicating about 8 ºC higher air temperature inside polyhouse and during that time the average air temperature inside polyhouse was about 28 ºC, which was optimum for the growth and development of tomato plants. Relative humidity was lower inside the polyhouse as compared to open field. Flowering, fruit setting and fruit maturity in polyhouse plants were advanced by about 3, 4 and 5 days, respectively compared to the crop raised in open field condition. Polyhouse plants had higher number of flower clusters/plant, flowers/cluster, flowers/plant, fruit clusters/plant, fruits/cluster and fruits/plant, and fruit length, fruit diameter, individual fruit weight, fruit weight/plant and fruit yield over open field condition. The fruit yield obtained from the polyhouse was 81 t/ha against 57 t/ha from the open field.

Carvalho *et al.* (2013) evaluated morphological behaviour of the initial phase of the black string bean crop with and without addition of nitrogen fertilization and in different cultivation shading environments. Both with the absence as well as with the addition of nitrogen fertilization in the black cowpea crop, more elevated values of height and diameter of stem in the plants cultivated in the external environment in relation to the shaded environment were observed.

Rajasekar *et al.* (2013) took up studies to screen ten vegetables for cultivation under shade net house (33% shade) and open field for year round production of vegetables. Tomato, eggplant, chilli, cucumber, cluster bean, radish, amaranthus, coriander and capsicum were grown in the summer and winter. The influence of environmental variables temperature, relative humidity and light intensity were studied. Relative humidity was always higher under shade net house than in open field during both seasons. Light intensity in the shade net house was lower than in the open field. Mean weekly temperature during summer and winter were higher under open field conditions than in the shade net house. Lower temperature caused plant height, number of branches, inter-nodal length, average fruit weight and yield per plant to be higher in the shade net house than in the open field.

2.2 PERFORMANCE OF VEGETABLE CROPS UNDER RAIN SHELTER

The plant growth and development at earlier stages was faster in plants under shade than open place (Choudhury and Bhuyan, 1992). Siddeque *et al*. (1993) reported about the possibilities of raising tomato crop successfully under plastic rain shelter during March to June and July to October, when crop could not be raised in the field without protection due to high rainfall.

Lalit *et al.* (2000) designed and tested a production system in which plant and soil surfaces are protected from direct rainfall using plastic shelters. On average, plastic shelters increased tomato and sweet pepper yields by 169% and 96% respectively, without any use of pesticides. Weed growth under the shelter was negligible and plants maintained greenness and production well into the fourth month after transplanting.

Hazarika and Phookan (2005) carried out a study to evaluate 27 tomato cultivars in relation to growth, yield and quality under plastic rain shelter during summer season. Out of all 27 cultivars, Yash recorded maximum yield of 1.76 kg/plant followed by Arka Ahuti and Arka Ashish. Yash also recorded the maximum plant height, braches number, fruit set percentage and yield per plant. The flowers per inflorescence were found highest in cultivar BT1 -on the other hand, Arka Ahuti recorded the highest retention of mature fruits.

According to Baliyan *et al.* (2014) the rainshelter is a suitable structure to improve vegetable production by reducing the damage caused by sunburn and birds. The impact evaluation of the project has given positive results whereby the total vegetable production and the income has increased by 162% and 103% respectively.

2.3 INFLUENCE OF DIFFERENT GROWING ENVIRONMENT ON PRODUCTIVITY AND QUALITY OF VEGETABLES

Deli and Tiessen (1969) observed higher number of branches and flowers in low temperature exposed capsicum plants. The flowers and ovaries formed were very small in sweet pepper plants which were exposed to constant temperature of 25 ^{0}C and were largest when plants exposed to low temperature at four leaf stages.

Rylski (1972) reported that soil temperature below 10 ^{0}C retarded growth and development of chilli plants, while 17 ^{0}C was optimum. As the temperature raised, shoot growth were increased but root growth was retarded above 30^{0}C. Days to flowering were reduced from 87 to 65 under high temperature conditions.

Vooren (1980) reported that increasing night temperature from12^{0}C to 20^{0}C under greenhouse condition decreased the number of days taken for first flower production (earliness) with 14 days in cucumber.

Karlse (1981) observed maximum growth of aerial parts in cucumber at 30^0C air and 25^0C root temperature. Gosselin and Trudel (1984) noticed a large increase in shoot dry weight, leaf area and fruit development in tomato with soil warming up to 24^0C.

Polowick and Sawahaney (1985) reported that, the low temperatures ($18/15^0$C) had more effect (negative response) on flowers and fruits of capsicum than intermediate ($23/18^0$C) temperatures. At higher night temperature ($36/27^0$C) maximum taller plants were observed in Okra cultivars (Tenka and Ormrdo, 1985).

Gosselin and Trudel (1986) observed maximum shoot dry weight and leaf area at root zone temperatures of 24 ^{0}C and 30^0C in pepper. While, maximum fruit weight and number of fruits occurred at 30^0C root zone temperature. Highest temperature (25^0C) range resulted in two week earlier harvest and improved fruit shape and firmness in tomato than at lowest constant temperature (Buitelaar and Janse, 1987).

Bakker *et al*. (1988) reported that yield of total and Class-1 fruits (kg/m^2) in sweet pepper were greatest at daily mean temperature of 21-21.3^0C.Hedge (1989) reported that in 3-year field trials with cultivars California Wonder, the plants receiving nitrogen at 0, 60, 120 or 180 kg/ha were irrigated. When the available soil moisture content (ASM) fell to 80, 60, 40 or 20 per cent, irrigation at 40 and 60 and ASM and nitrogen at 180 kg/ha gave the highest fruit yields (15 t/ha for the irrigation treatments and 18 t/ha for the Nitrogen rate).

Shi *et al.* (1991) noticed the highest net photosynthetic rate at 30^0C when plants were at an early growth stage and at 35^0C during mid late growth stage and at 35^0C large quantities of assimilates were transported to vegetative parts in cucumber plant. Dekoning (1992) reported that total yield in tomato was significantly higher at the higher night temperature (18.6^0C) than at low night temperature (16.3^0C). Marcellis (1993) reported that total leaf area and leaf weight per plant were greater at 25^0C than at 18^0C in cucumber.

Bhatt and Rao (1993) noticed higher net photosynthetic rate, growth rate and number of flowers in bell pepper at higher night temperatures. They further reported that at intermediate temperature, the number of four lobed fruits significantly increased and at low temperature the fruits obtained were short, blunt and unmarketable. In the greenhouse, the growth of the vegetative organs (leaves, stem and shoots) in brinjal and tomato were negatively affected by the high level of temperature (34^0C) (Malfa, 1993).

Chen *et al.* (1994) showed that sweet pepper fruits exposed to chilling stress (0.1^0C) showed increased respiration rates and ethylene production. The relative conductivity of the pulp and membrane permeability increased with chilling duration. These metabolic changes occurred before visible signs of chilling injury became apparent. However, an altering temperature treatment counteracted these changes and reduced the accumulation of alcohol, acetaldehyde and acetone, increased peroxidase and catalase activities, inhibited phenylalanine ammonia-lyase activity and reduced electrolyte leakage. The alternating temperature treatment was effective in reducing chilling injury in cold-stored sweet peppers.

Leonardi (1994) reported that maintaining temperature just above the minimum required for plant growth (about 16^0C until the end of vegetative growth and about 13 ^{0}C during flowering) increased yield and advanced the harvesting time of peppers.

The prime aim of a greenhouse is to grow plants and therefore high transmission of solar radiation in the wave band 400-700 nm is essential to maximize photosynthesis rates. The amount of structural material and the properties of the cladding will influence the proportion of incident radiation transmitted to the plants. The photosynthetically active radiation will be accompanied by radiation at other, mostly longer, wavelengths. All the radiation entering the greenhouse will contribute to the potential elevation of the greenhouse temperature above that of the external air. The greater the insulation properties of the house the greater will be the elevation, though as general rule those cladding materials that might be chosen for good thermal resistance will also tend to be less good at admitting radiation for plant growth (Day and Bailey, 1999).

Rose flower stems adapt to high VPD by decreasing leaf area for maintaining high sap flow rate per unit area. Dayan (2000) reported that rose flowers produced in greenhouses in Israel during summer had short thin stems carrying small buds with pale petioles, but cooling the air in the greenhouse improved flower quality.

Cooling has always been an important problem for polyhouse operators in warm climates, potentially limiting production and constraining profits. Polyhouse cooling is typically accomplished by ventilation, either mechanically, via exhaust fans or naturally and via wind (Willits, 2003).

Leaf area and other morphological properties (such as ratio of leaf area to stem cross- section area) of rose flower stem may change during growth under different environmental conditions. Stem length is the primary indicator for the economic value of cut-flower rose production. Shoots with length lower than 30 cm could be considered unmarketable, shoots with lengths between 30 and 60 cm could be considered of mean economic value and shoots longer than 60 cm could be considered of relatively high quality (Katsoulas *et al*., 2005).

Greenhouse cooling is quite difficult and complicated task, far more difficult than heating, since the cooling devices used in other kind of building demand huge investments and high energy consumption. The net solar radiation in the greenhouse, reaches 500-600 Wm^{-2} during summer. In order to obtain greenhouse air temperatures close to outside ones, a total of about 200-250 Wm^{-2} of sensible heat needs to be removed. Low cost methods such as forced ventilation, cooling pads, fog systems, screens, etc., or in most cases, a combination of the previous methods are used for the removal of redundant energy. The most common methods used for greenhouse cooling in Mediterranean areas are natural or forced ventilation (Kittas *et al*., 2005). Elevated temperatures will only be desirable when outside temperature conditions are below the optimum for plant growth. To make full use of an expensive structure through as much of the year as possible generally requires methods of cooling the house to be available. The most common is by natural ventilation, exchanging hot and humid air inside the house with cooler, drier air from outside.

2.4 COST ECONOMICS

Chandra *et al.* (1976) observed that additional cost involved in spraying NAA @ 10 ppm twice on chillies was only about Rs.50 per hectare and the increased yield of more than 20 per cent compensated the additional cost involved in production. Hoon and Vander (1979) while studying the cost economics of cultivation of freesia for cut flowers in greenhouse reported that returns remained the same continuously for three years (1976-1978), however cost had risen considerably. A similar study conducted by Rijssel and Oprel (1979), revealed that in greenhouse cultivation of roses for three years cost of cultivation increased with time, but profitability declined greatly.

As per the suggestions of Starangh (1983) cultivation of gerbera for two years appeared to be more economical than for one year. Granges and Leger (1989) found that by increasing the plant density of capsicum from normal level of three plants per m^2 to six plants per m^2, yield was found to increase by 80 per cent and gross returns by 50 per cent under greenhouse conditions.

Gaye *et al.* (1992) reported that the net returns were more with plants grown under cover at highest population density in bell pepper. In an economic analysis made in capsicum with three plant spacing (30 x 30, 45 x 30 and 65 x 30 cm) under naturally ventilated greenhouse conditions and open field cultivation revealed that though wider spacing of 65 x 30 cm resulted relatively lower yield due to lower plant population but excellent quality fruits were obtained. Medium spacing of 45 x 30 cm resulted the highest net returns of Rs. 21,018/ 100m^2/year and higher cost benefit ratio of 1:2.60 because of excellent quality fruits fetching relatively good price (Rs.20/kg) as compared to those from open field conditions (Rs.2560/ 100m^2/ year) with least cost benefit ratio of 1: 1.65 (@ of Rs. 16/kg).

Khan (1995) reported that greenhouse cultivation resulted in higher returns by producing higher yields of good quality produce, its initial investments and maintenance costs were much higher than natural or traditional cultivation methods. Therefore growers should be provided with the same technology and structures at lower costs to suit the Indian conditions as it results in better feasibility and profitability.

Biradar (1996) found that although the initial investment for cultivation of gerbera under greenhouse was relatively high (Rs.330/ m^2). It was profitable since it resulted in a net profit of Rs. 58,000/100 m^2 /year. Similarly, cultivation of roses was found to be more profitable with net profit of Rs. 20,000/100/m^2 /year when cultivated under low cost greenhouse as compared to open conditions (Nagaraj, 1996).

2.5 DRIP IRRIGATION

Sivanappan *et al.* (1977) conducted experiments to compare drip irrigation with other methods and showed that farmers saves up to 80% water, reduces weed growth, improves germination and gives the same or sometimes more yield.

Hartmann (1986) used four levels of irrigation. They found that the highest irrigation level increased root weight by 15% and leaf production by 50% as compared with lowest irrigation level.

Mane *et al.* (1987) have conducted experiment on comparative study of drip and furrow method of irrigation for bhendi crop and revealed that drip irrigation method of irrigation recorded maximum yield of bhendi (17.72 t/ha). Drip method increased the yield by 16.14 per cent with water saving of 39.6 per cent when compared with conventional furrow method. The water use efficiency in case of drip method was nearly twice the furrow method.

According to (Nagendra Prasad, 1988) average conveyance loss of water in the basin method while irrigating 1 ha of land was 27.7 % where as these losses were found to be considerably less under trickle irrigation system.

Clemmens (1990) conducted a study to design and develop an automatic drip irrigation system. The study showed that labour cost and operational costs could be reduced by this system thereby achieving a highly economic and efficient irrigation application.

Locascio and Smajstria (1996) studied the effect of amount of water application and mulches for 3 years on irrigated tomatoes by applying water at 0.00, 0.25, 0.5, 0.75 and 1.00 times pan evaporation in one application per day. They found that fruit yield gets doubled with drip irrigation. The total yield was found highest with quantities of 0.75, 0.5 and 1.00 times pan evaporation and significantly lower with 0.25 and 0.5 times pan evaporation values.

Singh *et al.* (2000) made an attempt to study the effect of drip irrigation compared to conventional irrigation on growth and yield of Apricot, to work out its irrigation requirement. Drip irrigation at 80 per cent evapotranspiration of water gave significantly higher growth and fruit yield of 8.6 tonnes per hectare compared to that surface irrigation. Plastic mulch plus drip irrigation further raised the fruit yield to 10.9 tonnes per hectare. Drip irrigation besides giving a saving of 98 percent irrigation resulted in 3.3 metric tonnes per hectare higher fruit yield.

Singh *et al*. (2000) studied the yield, water requirement and economics of drip irrigation in litchi orchard at farmer's field in Uttar Pradesh. It was found that good quality marketable yield of litchi varied from 12.5 to 16 metric tonnes per hectare for drip system. The total volume of water applied was 282 mm for drip irrigation during four months of system operation. The benefit cost ratio was found to be 3.91 for drip irrigated litchi orchard compared to 3.05 for surface irrigated litchi.

Jain *et al.* (2001) conducted experiments on the response of potato under drip irrigation and plastic mulching. The highest water use efficiency was found to be 3.24 t/ha-cm for the treatment irrigated with drip system at 80 per cent level with mulch as compared with to 2.17 t/ha-cm control treatment.

Singh *et al.* (2001) carried out experiments to study the effect of different irrigation regimes of 100 percent potential ET (V), 0.8V, 0.6V, 0.4V, 0.2V at four fertility levels on cauliflower yield with and without mulch under drip system and its comparison with the surface irrigation system. The highest curd yield was obtained under 100 percent recommended dose of fertilizer with volume of water applied equal to 22 cm through drip irrigation without mulch.

Singh *et al.* (2001) conducted studies on drip irrigation resulted in significant increase in production and water use efficiency of potato. At Udaipur it was reported that besides saving in water, the yield of potato tubers was high and weed growth was least in drip irrigation compared to surface irrigation.

Singandhube *et al.* (2003) conducted a study to determine the response to urea fertilizer with drip irrigation and compared with conventional furrow irrigation for two years. Application of nitrogen through the drip irrigation in ten equal splits at eight days interval saved 20 to 40 percent nitrogen as compared to the furrow irrigation when nitrogen was applied in two equal split. Similarly, 3.7 to 12.5 percent higher fruit yield with 31 to 37 percent saving of water was obtained in the drip system. Water use efficiency in drip irrigation, on an average nitrogen level was 68 and 77 percent higher over surface irrigation in 1995 and 1996, respectively. At a nitrogen application rate of 120 kg/ha, maximum tomato fruit yield of 27.4 and 35.2 tonnes per hectare in two years was recorded.

Yuan *et al*. (2006) studied the effects of different amount of irrigation water on the growth and yield of cucumber under a rainshelter for two seasons in Yamaguchi University, Japan. For spring experiment, the amount of irrigation water applied was 0.50, 0.75, and 1.00 times of water surface evaporation (Ep) and regimes were denoted as Ep0.50, Ep0.75, and Ep1.00. Same method for autumn experiment, regimes were denoted as Ep0.75, Ep1.00, Ep1.25, Ep1.50, and Ep1.75. The results showed that amount of irrigation water significantly affected plant growth and fruit production. Plant height and biomass increased, but specific leaf weight (SLW, g/m^2) decreased with increasing amount of irrigation water.

Stanislaw and Jacek (2008) carried out a study on the influence of surface and subsurface drip irrigation on the yield and quality of roots of parsley grown on ridges and on flat ground was carried out. Irrigation water was supplied via drip lines, which in subsurface irrigation were placed at a depth of 50 mm below the surface of the ridges, along the centre line between two rows of plants. In the case of surface irrigation, the drip lines were placed on the surface of the ridges between two rows of plants. Irrigation started when soil water potential was between -30 and -40 kPa. Nitrogen fertilizers (100 $kgha^{-1}$) were applied in two doses. The first dose was applied pre-plant, while the second one was delivered by fertigation. In the control treatment without irrigation, the second dose of nitrogen was applied by broadcasting. Both surface and subsurface irrigation used in the cultivation on ridges and on flat ground had a significant effect on the marketable yield of parsley roots. However, no significant differences in the yield between surface and sub- surface drip irrigation were found. The yield of non-marketable parsley roots in flat cultivation was twice as high as that in ridge cultivation. Parsley plants cultivated on ridges produced significantly longer, better-shaped storage roots compared to those cultivated on flat ground. Surface and subsurface drip irrigation significantly decreased the total N and K content in parsley roots.

Sefer and Gulsum (2009) conducted study to investigate the effects of drip irrigation methods and different irrigation levels on yield, quality and water use characteristics of lettuce cultivated in solar green house. The result showed that the highest yield was obtained from subsurface drip irrigation at 10 cm drip line depth and 100 percent of Class A Pan Evaporation rate treatment. The water use efficiency and irrigation use efficiency increased as the irrigation was reduced.

Deepa *et al*. (2010) conducted a study to standardize the irrigation requirement of salad cucumber grown in polyhouse. The experiment had five irrigation treatments with six replications. Two types of irrigation basin and drip were practiced. The irrigation treatments include drip irrigation with 1, 1.5, 2 and

2.5 lit/day of water. From the study it was found that drip irrigation has a positive effect on growth and yield of crop. Crops drip irrigated with 1.5 l/plant/day performed well with a water use efficiency of 121. Drip irrigation in comparison with the surface irrigation has given higher yield throughout the crop period. And also drip irrigation has shown larger soil moisture content a day after irrigation, while the conventional surface irrigation has least soil moisture content.

Majid and Fereydoun (2011) conducted a study to determine the effect of different irrigation methods on crop yield. Two irrigation methods, i.e. surface irrigation (SI) and drip irrigation (DI) were applied to cantaloupe between emergence and harvest during 2004 and 2005 growing seasons. The statistical results of study indicated that irrigation method significantly (P = 0.01) affected crop yield. The maximum crop yield of 27.1 t $ha^{-1}$was obtained in case of DI treatment and the minimum crop yield of 22.5 t ha^{-1} was recorded in case of SI treatment.

Zhang *et al*. (2011) studied the effect of drip irrigation scheduling on the yield and quality of cucumber fruits. The irrigation water amounts were determined based on the 20 cm diameter pan (*Ep*) placed over the crop canopy, and cucumber plant was subjected to three irrigation water levels (I1, 0.6 *Ep*; I2, 0.8 *Ep*; and I3, 1.0 *Ep*). The results showed that the cucumber fruit yield increased with the improvement of irrigation water. Irrigation water increased yields by increasing the mean weight of the fruits and also by increasing fruit number.

Ghaderi *et al*. (2012) conducted a study to determine the effects of deficit irrigation after the onset of flowering on lint yield and seed quality of cotton (*Gossypium hirsutum* L.) with a drip irrigation system were evaluated during 2006 and 2007 in the northern Iran. After the onset of flowering, four irrigation regimes (0, 40, 70 and 100% of Class A pan evaporation (%PE)) were applied when the cumulative evaporation amount from class A pan reached approximately 40-50 mm. Lint yield showed a quadratic response to %PE and maximum lint yields were achieved with 82 and 91% PE irrigation regimes in 2006 and 2007, respectively and seed quality (based on standard germination and seed vigor tests) increased with a decrease in deficit irrigation. Thus when the amount of applied water was reduced by 30 (70% PE) and 60% (40% PE), decrease in lint yield was about 4 and 14%, respectively. The results of this study showed that irrigation treatments of 40-70% PE would be optimum for lint yield and seed quality production under drip irrigation.

2.6 FERTIGATION

The advantages of the use of fertigation in a drip irrigation system include reduced labour, increased fertilizer efficiency and the increased flexibility of fertilizer application. Fertigation allows nutrient placement directly into the plant root zone during critical periods of nutrient demand (Mikkelsen, 1989).

Bachav (1995) conducted a field experiment on fertigation by comparing fertigation with NPK over farmer's fertilizer practice with conventional fertilizers in terms of yield, quality and monetary returns. Fertigation at weekly intervals was found more convenient and economically profitable for the farmers.

Drip irrigation generates a restricted root system requiring frequent nutrient supply. Nutrient requirement may be satisfied by applying fertilizers in irrigation water. Maximization of crop yield and quality and minimization of leaching losses below the rooting volume may be achieved by managing fertilizer concentration in measured quantity of irrigation water according to crop requirement (Hagin and Lowengart, 1996).

Highest fruit yield of 45.7 t/ha was obtained for tomato with application of recommended dose of fertilizers comprising polyfeed (19:19:19), MAP (12:60:0) and urea through fertigation. The yield were nearly 22 -27 percent higher compared to yields obtained in crop which was provided with normal fertilizers through soil application (Prabhakar and Hebber, 1996).

Pawar *et al.* (1997) took up studies to assess the effects of fertigation through drip on the growth, yield and quality of banana. The result revealed that, for banana the fruit yield was significantly higher in normal planting than paired row planting. The fruit yield increased significantly with water soluble complex fertilizers compared to Nitrogen alone and it also increased significantly with an increase in fertilizer levels.

Shindhe *et al.* (1997) conducted field experiment to study the effect of water soluble fertilizers through drip on the growth and yield of cotton. The expression of growth and yield contributing characters of cotton due to normal planting was at higher magnitude compared to paired row resulting in higher seed cotton yield by 7.75 percent. Maximum seed cotton yield of 3.4 t/ha was obtained due to 100 percent of recommended fertilizer dose.

Neelam *et al.* (1998) conducted field experiments at IARI, New Delhi with four fertilizer levels of 100, 80, 60 and 40 percent. The yields of onion realized under different treatments of fertigation were compared with that achieved by conventional methods. Fertigation resulted in 60 percent saving of fertilizer for achieving same level of production compared to conventional method of fertilizer application.

Application of soluble fertilizer like urea and muriate of potash through drip irrigation could bring about substantial savings of 20-25 percent in fertilizer use, besides minimizing pollution of ground waters through nitrate – nitrogen leaching to a considerable extent. Fertigation also offers the possibilities of using nutrients matching the crop demand at different stages of crop growth (Srinivas *et al.*, 1999).

Singh *et al.* (2001) conducted field experiment in sandy loam soil to investigate the water and nutrient use efficiency of sprouting Broccoli grown on sandy loam soil using fertigation. Yields obtained showed that substantial saving in the fertilizer applied, to the extent of 20-40 percent could be accomplished through fertigation.

Singh *et al*. (2001) conducted field experiments to investigate the water and nutrient use efficiency of sprouting broccoli growing on sandy loam soil using fertigation. The treatments included application of the recommended fertilizer dose as soil application and irrigation through drip irrigation as well as three levels of fertigation viz. 100, 80, 60 percent of the recommended fertilizer doses. Flood irrigation with recommended doses was considered as control. Yield obtained indicated substantial saving in the fertilizer applied to the extent of 25 – 40 percent.

The effects of irrigation water level and nitrogen fertilizer on total canopy and wetted area basis of chilli in respect of yield, water saving and water use efficiency was studied on loamy sand soil by Singh *et al*. (2001). The highest yield of 3.03 kg/ha was recorded with water applied on total area basis along with 180 kg N/ha. The study suggested that it is better to schedule irrigation at 0.8 of E pan evaporation and apply on canopy area basis combined with 180 kg nitrogen per hectare to maximize the production.

Singh *et al*. (2001) conducted experiment on the response of drip irrigation and black plastic mulching on young mango trees. The study indicated that the biometric growth of the treatments irrigated at 60 percent level through drip system with plastic mulching performed better when compared to 80 percent and 100 percent levels of water use along with water saving of 20 – 40 percent.

Veeranna *et al.* (2001) conducted field experiments to investigate the effects of broadcast application and fertigation of normal and water soluble fertilizers at three rates through drip and furrow irrigation methods on yield, water and fertilizer use efficiency in chilli (*Capsicum annum*). Fertigation with 80 percent water soluble fertilizers was effective in producing about 31 and 24.7 percent higher yield over soil application of normal fertilizers at 100 percent recommended level in furrow and drip irrigation methods respectively, with 20 percent saving of fertilizers and 36 percent saving of irrigation water.

Shataroopa *et al.* (2005) conducted an experiment at the Assam Agricultural University to investigate the effect of drip irrigation and plastic mulch on yield of Broccoli as compared to that over furrow irrigation. The water use efficiency was highest at lower level of ET replenishment by drip and with mulch. Maximum yield was obtained under drip irrigation replenishing 120 percent of ET depletion and under mulch.

Subby *et al*. (2005) was conducted a study to compare the effect of subsurface and surface drip irrigation on soil moisture distribution and growth of three years old pre-bearing mango in Agricultural Research Station, Andhra Pradesh. Soil moisture at the surface and near the dripper was the highest in the case of surface dripper and subsurface dripper placed at 30 cm depth.

Anitha (2006) did experiments on nutrient management in chilli based cropping system in Kerala. Nutrient levels significantly influenced the yield of crops in chilli based cropping system. Better growth and yield performance of chilli, French bean and amaranthus was observed when both chilli and intercrops were given 100 percent nutrient dose. The yield of intercropped chilli was 8917, 5598 and 4865 kg/ha at 100, 75 and 50 percent nutrient doses respectively

Vijayakumar *et al.* (2007) conducted studies at Agricultural Research Station Bhavanisagar to maximize the water and fertilizer use efficiency of drip system in brinjal crop. The experiments were laid out in Factorial Randomised Block Design with nine treatments which included three irrigation levels 100, 75 and 50 percent of pan evaporation along with three fertigation levels, viz. 125, 100 and 75 percent of recommended Nitrogen and Pottasium application by fertigation and replicated thrice. In brinjal higher yields with maximum shoot length and number of branches per plant were recorded for the treatment with 75 percent of PE with fertigation of 75 percent of recommended Nitrogen and Pottasium.

Yasser *et al.* (2009) reported the impact of fertigation scheduling on tomato yield under arid ecosystem conditions. Results revealed that tomato yields, water and fertilizer use efficiency had been enhanced by 25.6, 49.3 and 20.3 percent respectively under surface drip in comparison with solid set sprinkler irrigation system. The cost of tomato production under fertigation was lower than that when using traditional method of fertilization.

Growth performance of eggplant (*Solanum melongena* L.) grafts was evaluated by Ndereyimana *et al*., 2014 under different spacing and fertigation levels. The field trial was designed in a strip plot design with four levels of spacing and three levels of fertigation, F1: 75 % RDF (Recommended Dose of Fertilizer), F2: 100 % RDF and F3: 125 % RDF, replicated four times. The plant height, number of branches per plant and plant spread in East-West (EW) and North-South (NS) directions were recorded. Spacing and fertigation levels significantly affected eggplant growth and excellent growth performance for eggplant grafts was noticed under 1.5 m x 1.5 m + 100 % RDF which is recommended at the end of this study. Eggplant growers should be encouraged use eggplant grafts in combination with adequate plant spacing and nutrition since these contribute to the improved plant growth and development leading to greater productivity.

CHAPTER 3

MATERIALS AND METHODS

There are different arguments regarding the adaptability and advantages of polyhouse, rainshelter and open field precision farming in Kerala. In the present study an attempt was made to compare the performance of crop under naturally ventilated polyhouse and rainshelter in relation to open field cultivation. Materials used and methodology adopted for the study are briefly discussed in this chapter.

3.1 STUDY AREA

The experiment was carried out in the instructional farm of KCAET, Tavanur, Kerala. The study was conducted using cowpea during the months of August to December, 2014 under naturally ventilated polyhouse, rainshelter and open field of PFDC, KCAET, Tavanur, Kerala. The site is situated on the cross point of 10^{o} 51’18” N latitude and 75^{o} 59’ 11” E longitude at an altitude of 8.54 m above mean sea level.

3.2 EXPERIMENTAL DETAILS

Crop: Cowpea- Yard long bean (*Vigna unguiculata* subsp.*sesquipedalis*). It is a trailing type legume crop, belongs to the family Fabaceae.

Area: 100 m^2 each

Growing structures/ condition : Naturally ventilated polyhouse

: Rainshelter

: Open field

Design: CRD

Replications: Fifteen (Five in each treatment)

Treatments: Three

Spacing: 1.5×0.45 m

3.3 PROTECTED STRUCTURES

3.3.1 Naturally ventilated polyhouse

Naturally ventilated polyhouse of area 292 m^2 (36 m in length and 8 m in width) is oriented in East-West direction. Its frame is made up of galvanized steel pipe and covered with 200 micron UV stabilized polyethylene film. Two sides are covered with insect proof net of 40 meshes for natural ventilation and protection against entry of insect pests. For the present study an area of 100 m^2 (20×5 m) was selected inside the polyhouse to cultivate cowpea. Specifications and layout of the naturally ventilated polyhouse is given here under (Table 3.1 and Fig. 3.1).

Table 3.1 Specifications of naturally ventilated polyhouse

Sl No	**Particulars**	**Specification**
1	Green House type	Naturally ventilated, tropical with corridor, fixed roof vent, (saw tooth type)
2	Column height	3 m
3	Centre height	6 m
4	Inside area	292 m^2
5	Structure	
	External column pipe	2” diameter, 2 mm thick galvanized steel B class
	Internal column pipe	1.5” diameter, 2 mm thick galvanized steel B class
	Arch	1.5” diameter, 2 mm thick galvanized steel B class
	Gutter	2 mm galvanized
	Entrance	Double door sliding with sealing brushes
6	Ventilation	
	Side walls	Covered with 40 mesh UV stabilized net
	Roof covering	UVA 205 N clear, Thermic anti drip, 5 layer, antivirus, 200 micron polythene with 85% light transmission
	Roof vent	At least 0.75 m width covered with 40 mesh UV stabilized insect proof net
	Shade net screen inside	Black 50% UV stabilized movable

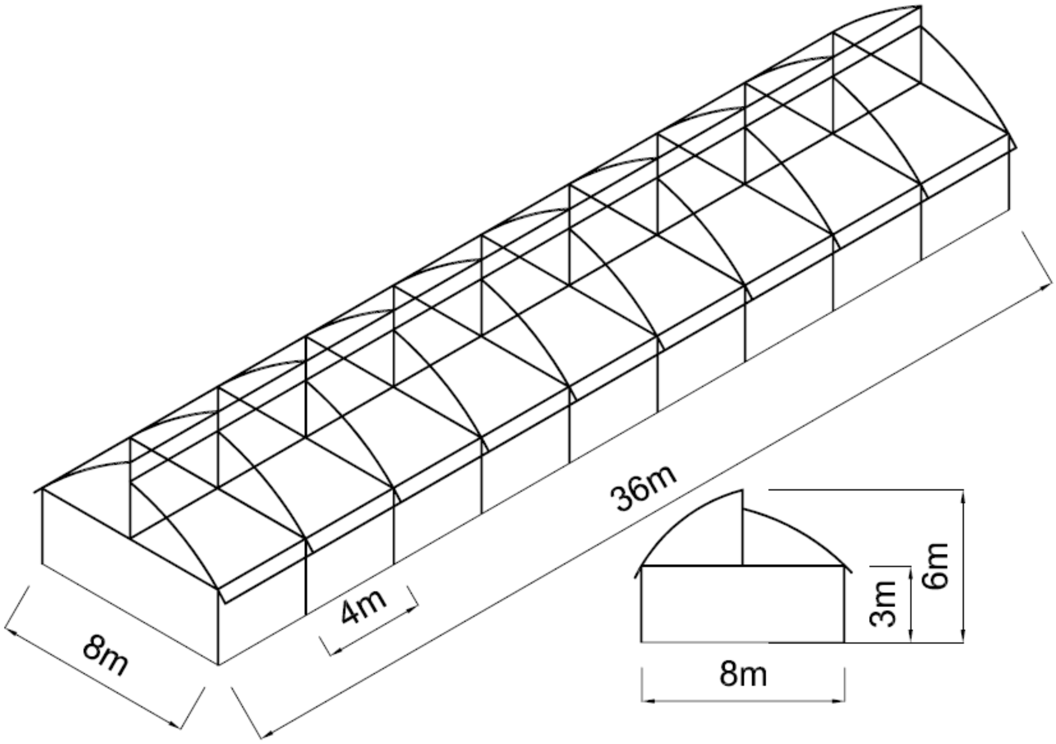

Fig 3.1 Schematic diagram of naturally ventilated polyhouse

3.3.2 Rainshelter

Rainshelter having an area of 100 m^2 (20 m in length, 5 m in width and 3 m in height) is oriented in East-West direction. Its frame is made up of galvanized iron pipe and covered with 200 micron UV stabilized polyethylene film. Specifications of rainshelter are given in Table 3.2 and Fig. 3.2 shows the schematic diagram of structure.

Table 3.2 Specifications of rainshelter

Sl No	Particulars	Specification
1	Rain shelter type	Gable shaped
2	Column height	2 m
3	Centre height	3 m
4	Inside area	100 m^2
5	Structure	
	Column pipe	1.5” diameter, 2 mm thick galvanized iron
6	Ventilation	

Table 3.2 Continued

	Side walls	Covered with 50 mesh net on all four sides at a height of 1 m from ground
	Roof covering	200 micron polythene with 85% light transmission

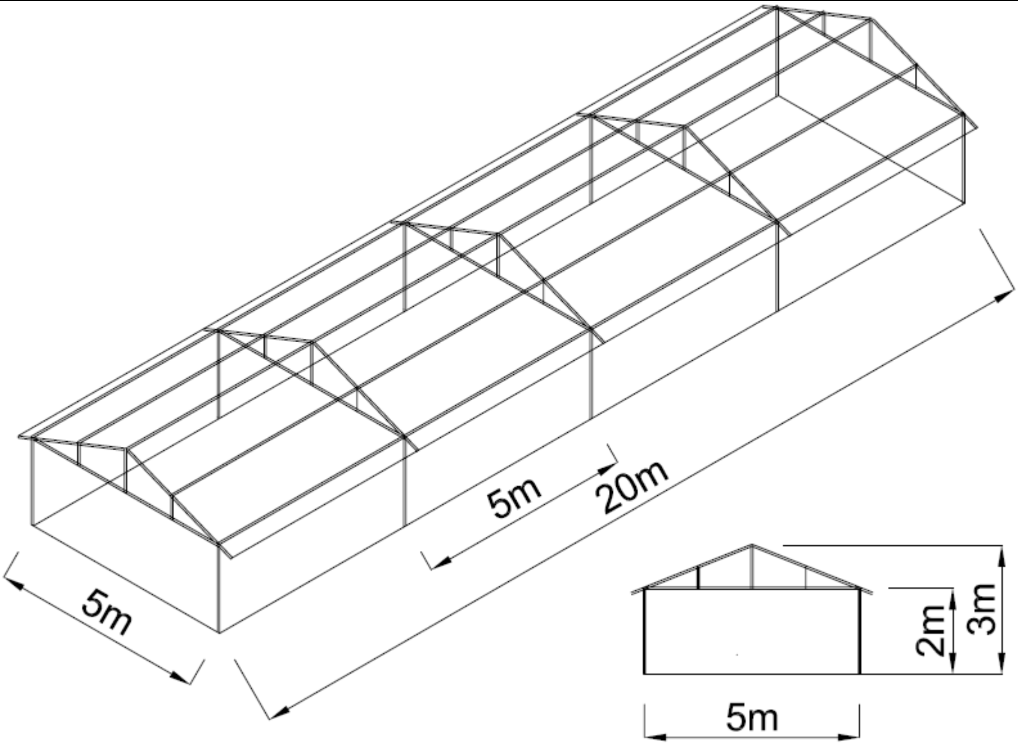

Fig 3.2 Schematic diagram of rainshelter

Plate 3.1 Naturally ventilated polyhouse

Plate 3.2 Rainshelter

Plate 3.3 Open field

3.4 EXPERIMENTAL PROCEDURE

An area of 100 m^2 (20×5 m) was selected inside the existing polyhouse and a rainshelter of size 100 m^2 (20×5 m) was constructed beside the polyhouse for cultivation of cowpea (Vellayani Jyothika). Beside the two structures another 100 m^2 (20×5 m) area in the open field was selected. The crop was raised in the polyhouse, rainshelter and in open field during the period of August to December 2014. All the cultural practices were done according to the Package of Practices Recommendations of KAU.

3.5 FIELD EXPERIMENT

3.5.1 Land Preparation

The land inside the polyhouse, rainshelter and open field were ploughed thoroughly using mini tiller**.** The soil type of the experiment plots were sandy loam. The field was left idle for one week after lime application. Farm yard manure was added to the field and dolomite applied at the rate of 435 kg/ha.

The manures used were:

Neem cake: 1 sack of 25 kg

Trichoderma: pack of 250g in 50 L water

Cow dung: 400 kg

3.5.2 Bed Preparation

Three beds each of convenient size (length 20 m, width 0.6 m and height 0.4 m) were prepared in polyhouse, rainshelter and open field. Area of each bed was 12 m², containing single row of cowpea. Every single bed contains 44 plants at a spacing of 45 cm. Spacing between beds were kept 1.5 m. The experimental plots after bed preparation is shown in plates 3.4 to 3.6.

Plate 3.4 Polyhouse after bed preparation

Plate 3.5 Open field after bed preparation

Plate 3.6 Rain shelter after bed preparation

3.5.3 Crop Variety

Cowpea var. Vellayani Jyothika is a trailing type legume released by KAU, was used for the trial. Sowing was done on 27.8.2014. The seeds were sown at a depth of 2 cm from ground level. The seeds were treated in *Pseudomonas* solution for one day. Laterals with inline drippers were laid on each bed providing water and fertilizer effectively up to root zone depth.

3.5.4 Fertilizer Application

Fertilizers were applied through drip irrigation system using venturi assembly. Duration of the crop is 120 days, so the fertigation was scheduled as 40 splits with the frequency of once in three days from planting till the end of crop. Weekly foliar application of micronutrients was also provided. Fertigation schedule for cowpea is shown in Table 3.3.

Table 3.3 Fertigation schedule for cowpea

Crop	Yard long bean
Total NPK	175:105:310 kg ha^{-1}
Basal P	52.50 kg ha^{-1}
Establishment stage (split into 6 doses)	25.50:7.875:46.50 kg ha^{-1}
Vegetative stage (split into 12 doses)	51.0:15.75:93.00 kg ha^{-1}
Fruiting stage (split into 22 doses)	93.50:28.90:170.50 kg ha^{-1}

3.5.5 Inter Cultural Operation and Weeding

Manual weeding was done in a periodic manner. Drip irrigation controlled the growth of weeds as it gives only sufficient amount of water to each plant.

3.5.6 Plant Growth Regulators and Protection Measures

Plant protection measures were adopted for incidence of pest and disease attacks using recommended dose of chemicals on time. The various pests and diseases observed in all the treatments along with their management practices adopted are given in Table 3.4.

Table 3.4 Details of application of fungicides and pesticides

Name of fungicides / pesticides/ biocontrol agents	Amount used	Pest/disease	Treatment
Pseudomonas	Seed treatment @ 10 g/kg seeds	For managing seed borne diseases	All treatments
Acephate 75 SP	2g per litre	Thrips	Open field
Imidacloprid 17.8 SL	3 ml/10 litre	Aphids	Open field
Carbendazim 50 WP	2g per litre	Wilt	All treatments
Chlorantraniliprole 18.5 SC	3ml per 10 litre	*Spodoptera litura*	Polyhouse
Copper oxy chloride 50 WP	3g per litre	Anthracnose and black wine	Open field
Copper hydroxide 77 WP	2g per litre	Anthracnose and black wine	Open field
Spiromesifen 240 SC	1 litre per litre of water	Mites	Polyhouse

3.5.7 Installation of Drip System and Fertigation Units

The plants were irrigated daily through drip irrigation system. Irrigation water was pumped using 5hp monoblock pump set and conveyed through the main line of 63 mm diameter PVC pipes after filtering through the disc filter. The installation of the irrigation system was done on 20-08-2014. From the main pipe, sub main of PVC pipes (50 mm) were installed. From the sub mains water is conveyed to LDPE laterals of diameter 16 mm. Inline drippers at spacing of 40 cm were used for irrigation. One lateral was provided for one bed and the discharge rate of single dripper is 2 lph. Venturi injector was installed along with irrigation unit.

Plate 3.7 Control head of drip irrigation system

3.6 OBSERVATIONS

3.6.1 Vegetative Parameters

3.6.1.1 Plant Height (cm)

Five plants were tagged at random in each treatment for recording the plant height at 30, 40 and 50 days after planting (DAP). The plant height was measured from the ground level to the growing tip of the main stem. The average height was calculated and expressed in centimetres.

3.6.1.2 Internodal Length (cm)

Intermodal length of the tagged plants was recorded at 30, 40 and 50 days after planting (DAP).

3.6.1.3 Number of Branches

Numbers of branches in the tagged plant were counted at 30, 40 and 50 days after planting (DAP).

3.6.1.4 Time Taken for Flower Initiation

Number of days taken from the date of sowing to opening of first flower was recorded in each structure.

3.6.2 Yield Parameters

3.6.2.1 Number of Pods per Plant

The number of mature pods that were harvested from the tagged plants in each picking was recorded till the final harvest.

3.6.2.2 Average Length of Pods

The fresh beans harvested from the labelled plants from each treatment were measured and average length was recorded in cm.

3.6.2.3 Yield per Plant (kg)

The weight of mature pods harvested from each picking was recorded till final harvest and total yield of pods per plant was recorded in kilograms.

Plate 3.8 Harvested cowpea

Plate 3.9 Crop stand inside the polyhouse

Plate 3.10 Crop stand inside the rainshelter

Plate 3.11 Crop stand in the open field

3.6.3 Weather Parameters

Following weather parameters were recorded from the time of sowing to that of last picking of pods inside the polyhouse and rainshelter and from the open field.

3.6.3.1 Temperature (^{o}C)

Air temperature inside the protected structures and from the open field was recorded by using thermo hygrometer daily and expressed as mean monthly data.

3.6.3.2 Relative Humidity (%)

The relative humidity inside the protected structures and from the open field was recorded by using thermo hygrometer at daily interval and expressed as mean monthly data.

3.6.3.3 Soil Temperature (^{o}C)

Soil temperature inside the protected structures and from the open field at a depth of 10 cm was recorded by using thermocouple thermometer at daily interval.

3.6.3.4 Rainfall

In order to compare the effect of rainfall on growth and yield of cowpea, the rainfall data during the crop growth period was recorded.

3.7 SOIL AND WATER PARAMETERS

3.7.1 Soil Properties

3.7.1.1 Particle Size Analysis

The analysis for grain size distribution of soils was done by sieving. Dry sieve analysis was carried out using 4.75mm, 2mm, 1mm, 600µm, 425µm, 300µm, 212µm, 150µm, and 75µm size sieves. Sieving was done using sieve shaker and weight of soil retained in each sieves were noted.

3.7.1.2 Soil Testing

Soil testing is a scientific tool to assess nutrient composition of soil. Soil collected from the experimental sites was analyzed for the nutrient composition (N, P and K) and pH.

3.7.1.3 Soil Moisture Constants

Laboratory analysis for determination of soil moisture constants was carried out with the help of pressure plate apparatus developed primarily by Richards (1949, 1954). The apparatus consists of ceramic pressure plate or membranes of high air entry values contained in airtight metallic chambers strong enough to withstand high pressure (15 bars or more).The apparatus enables the determination the 2 important soil moisture constants viz. field capacity and permanent wilting point.

Plate 3.12 Pressure plate and pressure membrane apparatus

Before the analysis both the porous plates and the soil samples were saturated and the saturated soil samples (undisturbed or disturbed) were placed on the plates and transferred to the metallic chambers. The chamber was closed with wrenches to tighten the nuts and bolts at the required torque for ceiling it. The pressure plate apparatus was filled with compressed air in the chamber and valves were adjusted to apply varied pressures from the compressor. Each pressure was applied for long duration of 48 hours until the drainage of water was complete and no water dripped from the sample through the outlet. The moisture retained in media after application of varied pressures viz, 1/3, and 15 bars was determined by gravimetric methods.

3.7.2 Water Quality Parameters

Bore well water was used for irrigation. The water was pumped from bore well of 6 m depth near the experimental field. The quality of irrigation water was assessed at Radiotracer laboratory, College of Horticulture, Kerala Agricultural University.

3.8 ECONOMICS

Economics of cowpea cultivation under polyhouse, rainshelter and open field conditions were worked out by considering the present price of inputs and produce.

3.9 STATISTICAL ANALYSIS

The data pertaining to growth and yield parameters were tabulated based on treatment and replication wise. The data was statistically analyzed by SPSS 16.0 and means were separated by Tukeys test.

CHAPTER 4

RESULTS AND DISCUSSION

Results obtained from the study "Comparative Evaluation of Naturally Ventilated Polyhouse and Rainshelter on the Performance of Cowpea" are discussed in this chapter after analyzing the observations taken during the course of work.

4.1 EVALUATION OF SOIL PROPERTIES

Soil properties like nutrient composition, pH, soil physical properties and soil moisture constants were evaluated for polyhouse, rainshelter and open field.

4.1.1 Soil Nutrient Analysis

Test result of nutrient composition (N, P, and K) and pH of soil samples are given in Table 4.1. The soil inside the polyhouse is neutral and the soil inside the rainshelter and open field are slightly acidic in nature. Value of pH in the range of 5.5 to 6.5 is ideal for the cultivation of yard long bean. The result shows that medium quantity of Nitrogen, Phosphorus and Potassium are available in the soil inside polyhouse. In the case of rainshelter and open field, the quantity of Nitrogen is low and medium quantity of Phosphorus and Potassium are available in the soil. Hence the nutrient composition of soil in the experimental plots is almost the same.

Table 4.1 Initial soil nutrient status

Location	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	pH
Polyhouse	250.88	27.3	213.92	7.1
Rainshelter	225.75	30	160	6.32
Open field	238.33	24.7	197.12	6.12

4.1.2 Particle Size Analysis

Soil samples from the experimental plots were analyzed for particle size distribution using sieve analysis and the results are given in Appendix I, Appendix II and Appendix III respectively. Soil texture of all the samples was sandy loam.

4.1.3 Soil Moisture Constants

Pressure plate apparatus was used to determine the two important soil moisture constants viz. field capacity (FC) and permanent wilting point (PWP). Field capacity of soil inside polyhouse, rainshelter and open field were 12.8%, 11.6% and 11.9% respectively. Permanent wilting point of soil inside polyhouse, rainshelter and open field were 8.7%, 7.3% and 7.6% respectively. Field capacity and Permanent wilting point of soil in the experimental plots was almost same.

4.2 Irrigation Water Quality

Quality of irrigation water was tested at radiotracer laboratory, College of Horticulture, Kerala Agricultural University. The test results are given in Table 4.2. The results show that the water in the well was safe for irrigation.

Table 4.2 Results of water sample analysis

Sl.No	Parameters	Sample 1	
		Quantity	Remarks
1	pH	6.3	Neutral
2	Electrical Conductivity (dS/m)	0.19	Safe
3	Carbonates (me/L)	Nil	Safe
4	Bicarbonates (me/L)	2.0	Moderate
5	Copper (Cu) (mg/L)	ND	Safe
6	Zinc(Zn) (mg/L)	ND	Safe
7	Iron(Fe) (mg/L)	0.031	Safe
8	Manganese(Mn) (mg/L)	0.298	Safe
9	Calcium(Ca) (mg/L)	3.615	Safe
10	Magnesium(Mg) (mg/L)	4.604	Safe
11	Mg/Ca ratio	1.27	Safe
12	Sodium(Na) (mg/L)	11.7	-
13	Potassium(K) (mg/L)	3.2	Safe
14	SAR	0.96	Safe
15	RSC(me/L)	1.44	Moderate
16	Boron (mg/L)	ND	Safe

4.3 WEATHER PARAMETERS

Growth, development, productivity and post-harvest quality of any crop is largely depend on the interaction between the plant genetics and the environmental conditions under which they are grown. Environment is the aggregate of all external conditions which influences the growth and development of crop, which play the dominant role in the crop production. Each crop has its own set of environmental conditions under which it grows best (Reddy *et al*., 1999). Generally, crops are not profitable unless they are adapted to the region in which they are produced. Raising a crop successfully means the crop must be productive and economical to grow under prevailing conditions.

The observed weather parameters viz. maximum and minimum temperature, relative humidity, soil temperature and rainfall for the months of September, October, November and December are presented and discussed here under.

4.3.1 Maximum and Minimum Temperature

Maximum and minimum temperatures in the morning and evening inside polyhouse, rainshelter and open field are given in Table 4.3 and Table 4.4 respectively. The maximum temperature (39.1ºC) was recorded under naturally ventilated polyhouse in the month of September and minimum temperature (19.6ºC) was recorded under open field in the month of December. Temperature inside the polyhouse was higher than that in rainshelter and open field in all the four months. Temperature inside rainshelter was slightly higher than that in open field. The higher temperature inside structures above open field condition may be due to the green house effect. All the radiation entering the greenhouse will contribute to the potential elevation of the greenhouse temperature above that of the external air (Day and Bailey, 1999). Variation of maximum and minimum temperature in the experimental plots in the morning and evening are plotted in Fig 4.1 and Fig 4.2. The monthly average maximum and minimum temperature in the evening was slightly higher than that in morning in all the three cases. The rise in air temperature inside the polyhouse compared to open field ranges from 2.7°C to 3.4°C. In the case of rainshelter, the rise in air temperature compared to open field was 1.4°C to 2°C. These results agree with findings of Parvej *et al.* (2010) in which it was reported that from December to February the air temperature in the plyhouse and open field varied from 31.8 ºC to 39.1ºC and 23.3 ºC to 31.1ºC, respectively indicating about 8ºC higher air temperature inside polyhouse.

Table 4.3 Mean maximum and minimum temperature at 8.30 AM

Month	Temperature (°C) in the morning					
	Polyhouse		Rainshelter		Open field	
	max	min	max	min	max	min
September	34.7	26.7	33.4	25.5	32	23.5
October	35.5	26.5	34	25.6	32.3	23.6
November	35.3	25	34.2	23.8	32.3	22.7
December	36.1	24.5	34.1	23.7	32.7	21.9

Table 4.4 Mean maximum and minimum temperature at 4.00 PM

Month	Temperature (°C) in the evening					
	Polyhouse		Rainshelter		Open field	
	max	min	max	min	max	min
September	35.1	26.6	34.2	25.6	32.2	24
October	35.7	27	34.3	25.7	32.8	23.7
November	35.8	26.1	34.4	24.7	33	23
December	36.2	24.9	34.6	24	33.1	22

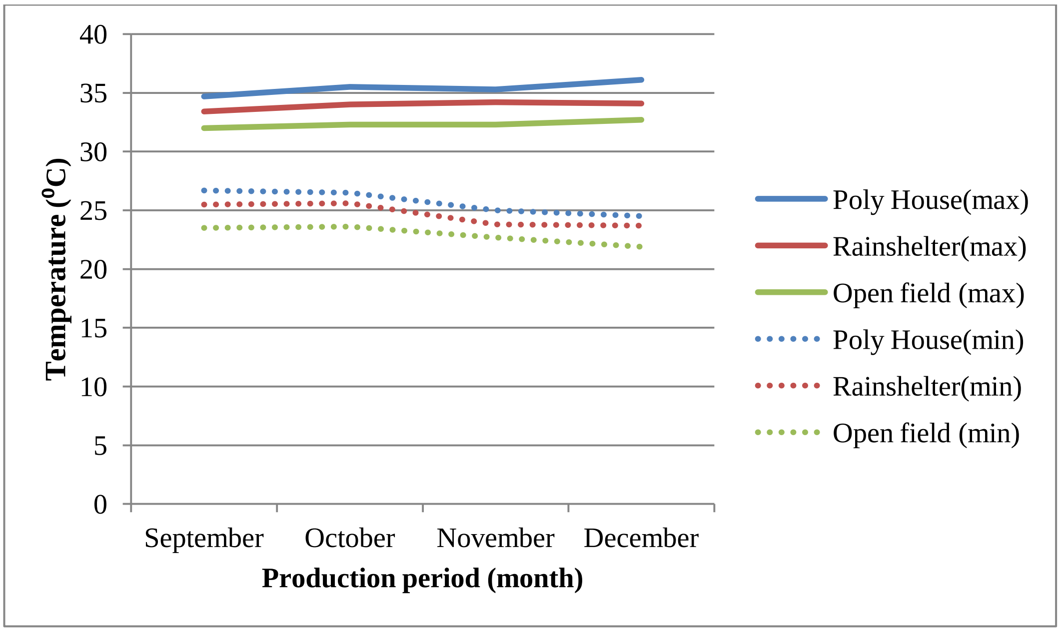

Fig 4.1 Maximum and minimum temperature variation inside polyhouse, rainshelter and open field at 8.30 AM

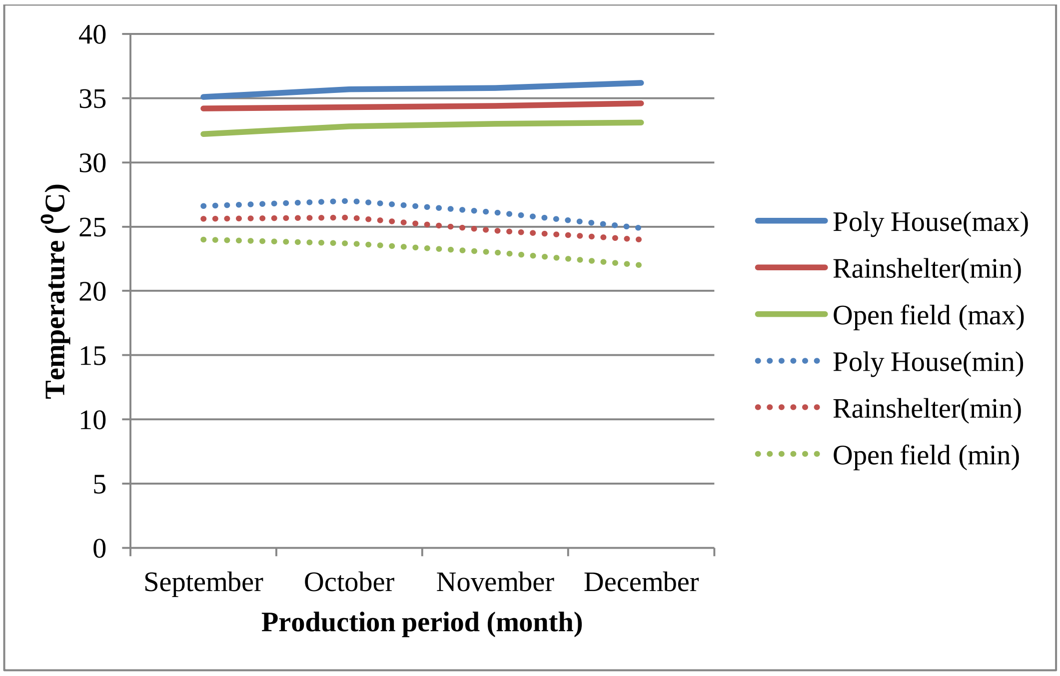

Fig 4.2 Maximum and minimum temperature variation inside polyhouse, rainshelter and open field at 4.00 PM

4.3.2 Relative Humidity

Atmospheric moisture also plays a significant role in crop growth and development. Relative humidity increases the availability of net energy for crop growth and prolongs the survival of crops under moisture stress conditions, which leads to optimum utilization of nutrients. It also maintains turgidity of cells (Reddy et al., 1999). The maximum relative humidity (84.5%) was recorded in the month of September in the polyhouse and the minimum relative humidity (54.7%) was recorded in the month of December in the open field. Variation of relative humidity in the experimental plots in the morning and evening are shown in Fig 4.3 and Fig 4.4 respectively.

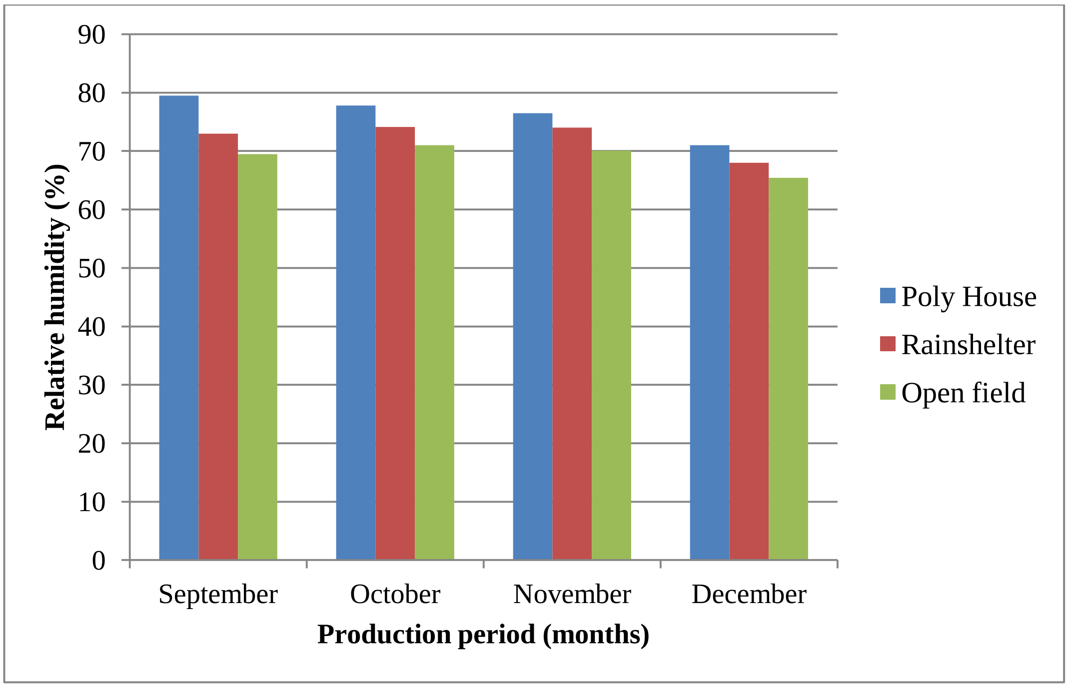

Fig 4.3 Variation of relative humidity at 8.30 AM

From the Fig 4.3 it is clear that the relative humidity inside polyhouse in the morning is higher than that in the rainshelter and open field throughout the production period. Similar results were observed by Nimje and Shyam (1993) in which it was reported that the relative humidity was higher inside the greenhouse than in the open field which influenced tomato growth and yield. The relative humidity inside rainshelter was also slightly higher than that at open field conditions. Similar readings were reported by Rajasekar *et al.* (2013).

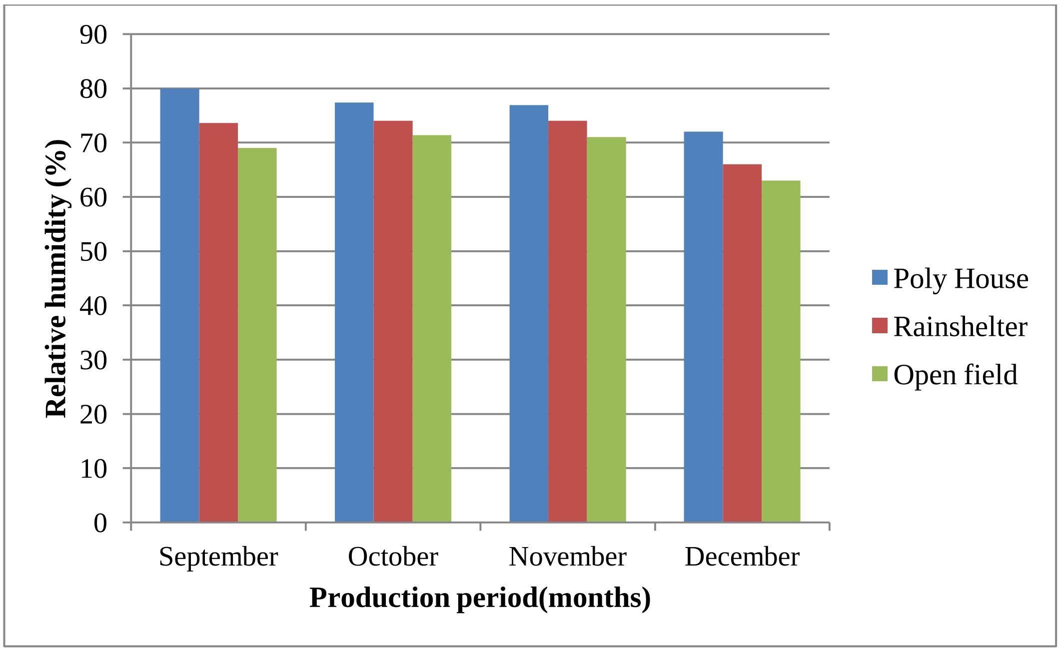

Fig 4.4 Variation of relative humidity at 4.00 PM

In the evening also the relative humidity was higher in polyhouse followed by rainshelter and open field (Fig 4.4).

4.3.3 Soil Temperature

Variation of soil temperature in the experimental plots in the morning and evening are plotted in Fig 4.5. Soil temperature was higher in polyhouse followed by rain shelter and open field throughout the production period. The maximum soil temperature (42 ^{0}C) was recorded in the polyhouse in the month of September and minimum soil temperature (29 ^{0}C) was recorded in the open field in the month of December. Soil in the polyhouse always maintained 3 to 5.5ºC higher temperature as compared to the soil in the open field irrespective of the growing periods of the crop. Soil under rainshelter maintained 0.2 to 2.6 ºC higher temperature with respect to soil in the open field (Fig 4.5). The higher temperature inside the structures may be due to the green house effect. Similar results were observed by Parvej *et al.* (2010) in which it was noted that soil temperature in the polyhouse was 2- 3 ºC higher than at the outside soil irrespective of the growing periods.

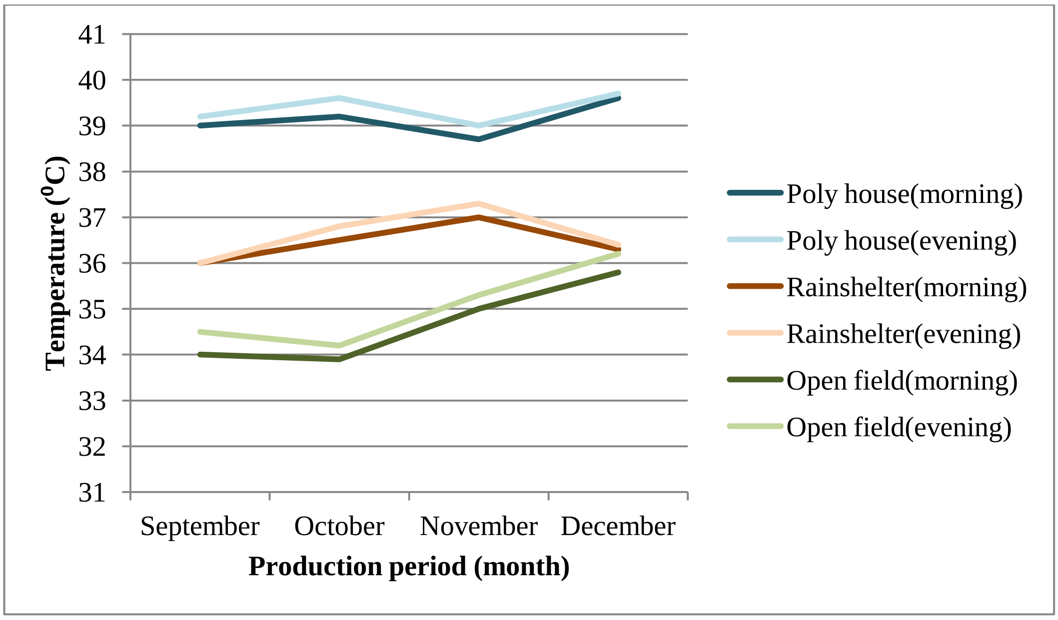

Fig 4.5 Variation of soil temperature in the experimental plots at 8.30 AM and 4.00 PM

4.3.4 Rainfall

The maximum rainfall (360.7 mm) was recorded in the month of October and minimum rainfall (6.3 mm) was recorded in the month of December. The rainfall recorded in September and November is 217.5 mm and 78.3mm respectively. The daily rainfall during the production period is plotted in Fig 4.6.

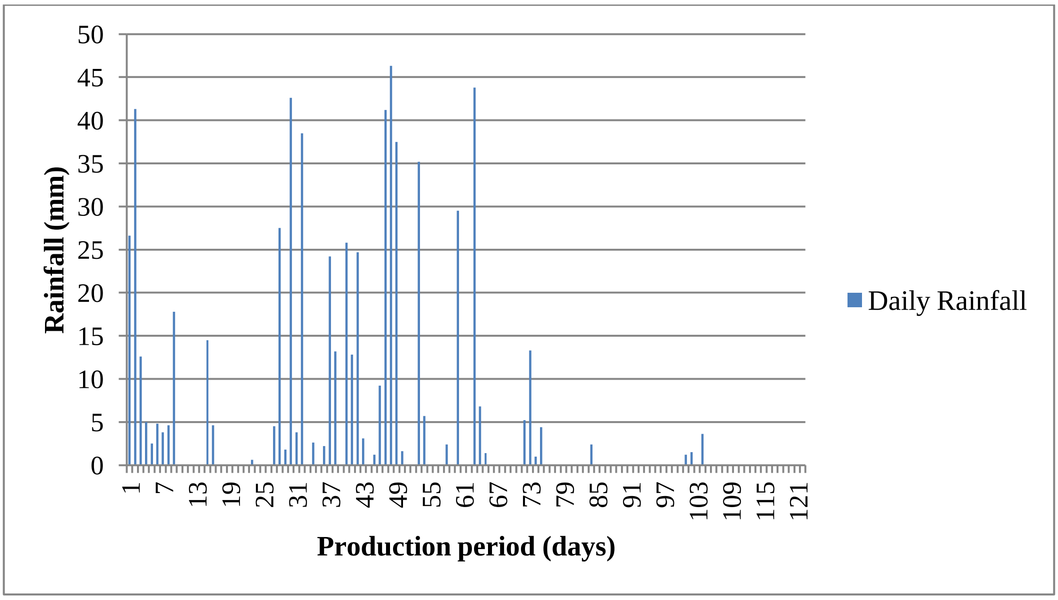

Fig 4.6 Daily rainfall during the production period

4.4 GROWTH PARAMETERS

4.4.1 Plant Height (m)

The data on plant height at different stages of crop growth as influenced by growing environment are shown in Table 4.5 and Fig. 4.7. The plant height of cowpea differed significantly due to growing environment at all stages of crop growth *viz.*, 30, 40 and 50 days after planting (DAP).

Table 4.5 Plant height (m) as influenced by growing environment at different stages of crop growth in cowpea

Treatments	Plant height (m)		
	30 DAP	40 DAP	50 DAP
T1- Polyhouse	2.43[a]	3.38[a]	4.47[a]
T2- Rainshelter	0.78[b]	1.37[b]	2.39[b]
T3- Open field	0.77[b]	1.19[c]	2.05[c]

DAP - Days after planting

At 30 DAP, among the different structures, plant height was maximum (2.43 m) in the polyhouse, which was significantly superior over the rainshelter and open field. There was no significant difference in plant height inside rainshelter and open field during this stage. At 40 and 50 DAP, the plant height was significantly higher in polyhouse followed by rainshelter and open field. The difference in plant height between rainshelter and open field were also significant. This may be attributed to the enhanced plant metabolic activities like photosynthesis and respiration due to favourable micro-climatic conditions that prevailed in the polyhouse and rainshelter as compared to open field. The results of higher growth rate in the polyhouse structure were reported by Maurer (1981) in bell pepper and More *et al.* (1990) in cucumber. The results of higher growth rate under shade net house were reported by Ryelski (1986) and El-Aidy *et al*. (1988) in sweet pepper.

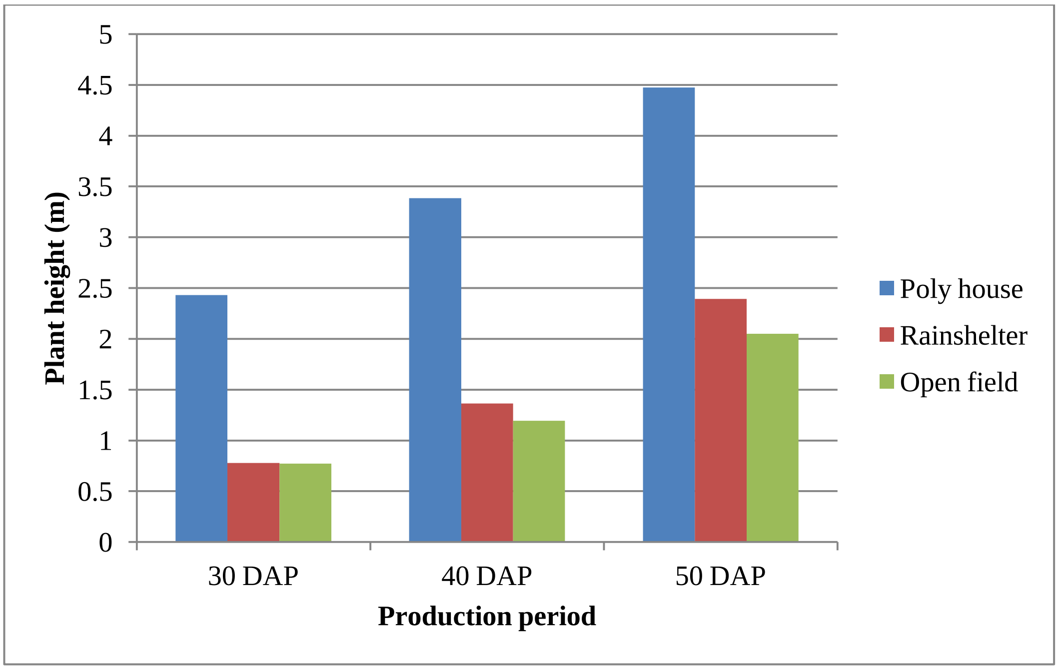

Fig 4.7 Plant height (m) as influenced by growing environment at different stages of crop growth in cowpea

4.4.2 Internodal Length (cm)

The data on internodal length at different stages of crop growth as influenced by growing environment are shown in Table 4.6 and Fig. 4.8. During the successive stages of crop growth *viz.*, 30, 40 and 50 days after planting (DAP), the internodal length of cowpea was found to be increasing and it was 43.10 cm at 50 DAP under naturally ventilated polyhouse followed by rainshelter and open field.

Table 4.6 Internodal length (cm) as influenced by growing environment at different stages of crop growth in cowpea

Treatments	Internodal length (cm)		
	30 DAP	**40 DAP**	**50 DAP**
T1- Polyhouse	38.13[a]	40.60[a]	43.10[a]
T2- Rainshelter	26.60[b]	29.07[b]	31.93[b]
T3- Open field	22.27[c]	23.73[c]	26.07[c]

DAP - Days after planting

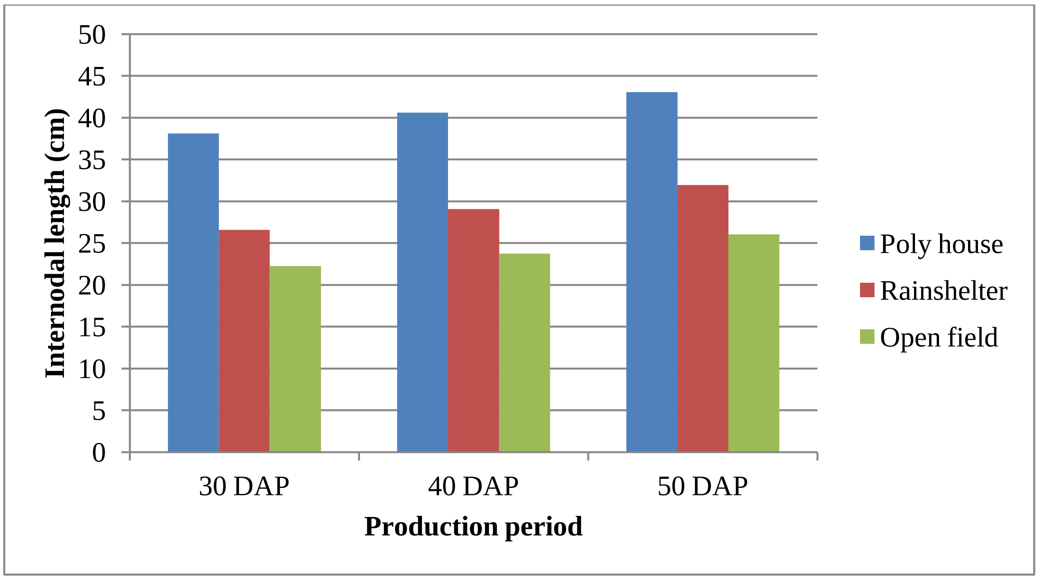

Fig 4.8 Internodal length (cm) as influenced by growing environment at different stages of crop growth in cowpea

The internodal length of cowpea differed significantly due to growing environment in all the stages of growth. The internodal length was significantly higher inside polyhouse followed by rainshelter and open field. Also internodal length was significantly higher in rainshelter over open field. The increase in internodal length inside protected structures may be due to the enhanced plant metabolic activities like photosynthesis and respiration due to favourable micro-climatic conditions that prevailed in the structures as compared to open field. This agrees with results of Ramesh and Arumugam (2010) on vegetables grown in the polyhouse and Ryelski (1986) and El-Aidy *et al*. (1988) in sweet pepper under shade net house.

4.4.3 Number of Branches

The data on number of branches at different stages of crop growth as influenced by growing environment are shown in Table 4.7 and Fig. 4.9. From Table 4.7 it is clear that the number of branches is more in open field over rainshelter and polyhouse at all growth stages. Number of branches inside rainshelter was more than that in polyhouse at 30 and 40 days after planting. The more number of branches in open field as compared to protected structures was noticed by Rajasekar *et al*. (2013) in which it was reported that cluster bean, bhendi and cucumber had more branches per plant in open field than in shadenet during both seasons. This indicates that this crop might require more light intensity for better growth and development (Marcelis and Hofman-Eijer, 1993).

Table 4.7 Number of branches as influenced by growing environment at different stages of crop growth in cowpea

Treatments	Number of branches		
	30 DAP	40 DAP	50 DAP
T1- Polyhouse	0.13[c]	0.33c	4.33[b]
T2- Rainshelter	0.80[b]	2.33[b]	4.47[b]
T3- Open field	2.93[a]	4.87[a]	6.80[a]

DAP - Days after planting

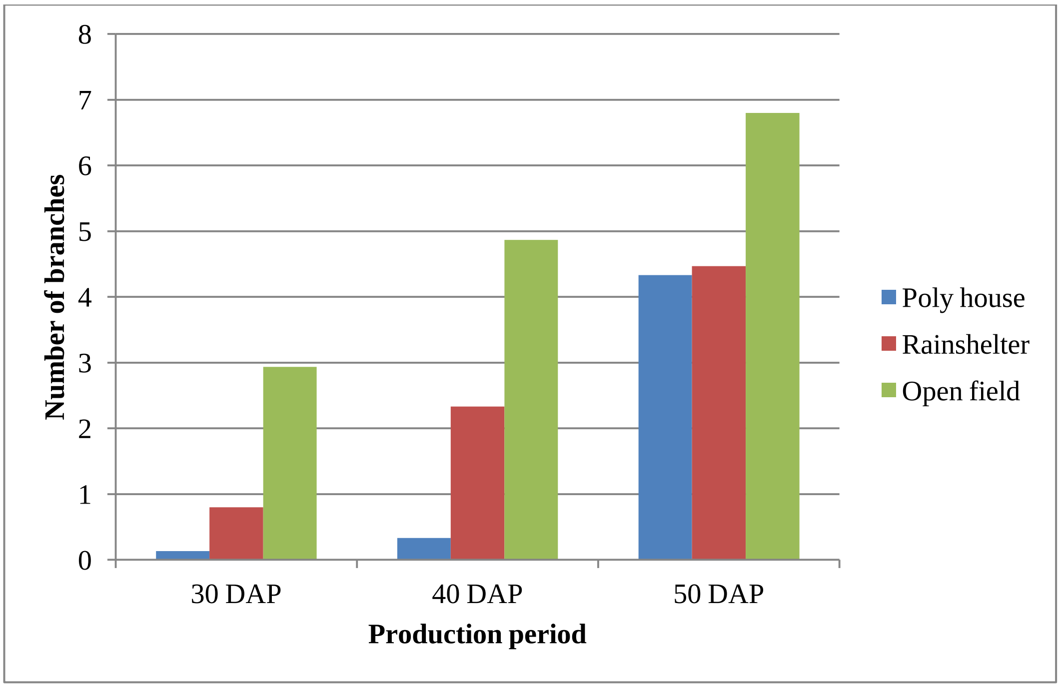

Fig 4.9 Number of branches as influenced by growing environment at different stages of crop growth in cowpea

4.4.4 Time Taken for Flower Initiation (Days)

Among the different structures, early flower initiation (39 days) was recorded in the polyhouse. The late flower initiation (42 days) was noted in the rainshelter and open field. Similar results were obtained by Rui *et al.* (1989) in capsicum. This agrees with the finding of Kang and Sidhu (2005) in which it was reported that polyhouse climate influenced the crops to open flower and mature of fruits earlier than open field.

4.5 YIELD PARAMETERS

4.5.1 Number of Pods per Plant

The data on number of pods per plant at different stages of crop growth as influenced by growing environment are shown in Table 4.8 and Fig. 4.10. At 55 DAP, number of fruits per plant was maximum (24.8) under open field, which was significantly superior over other growing structures. The least number of fruits per plant (2.47) was recorded in the rainshelter. The number of pods per plant was significantly more in open field during all growth stages except two stages (69 and 97 DAP). At 69 and 97 DAP, there was no significant difference in number of pods per plant. The more number of pods per plant in open field may be resulted because of the more number of branches per plant found in open condition. The increased number of branches and number of pods per plant in open field may be a special character of the cowpea variety (Vellayani Jyothika), which is not an exclusive polyhouse variety.

Table 4.8 Number of pods per plant as influenced by growing environment at different stages of crop growth in cowpea

Treatmens	Number of pods per plant						
	55 DAP	62 DAP	69 DAP	76 DAP	83 DAP	90 DAP	97 DAP
T1- Polyhouse	10.87[b]	13.40[b]	15.60[a]	14.13[c]	11.27[c]	10.53[b]	9.80[a]
T2- Rainshelter	2.47[b]	15.07[b]	12.33[a]	14.73[b]	14.93[b]	15.33[a]	10.33[a]
T3- Openfield	24.80[a]	23.60[a]	15.33[a]	17.27[a]	18.66[a]	16.93[a]	12.33[a]

DAP – Days after planting

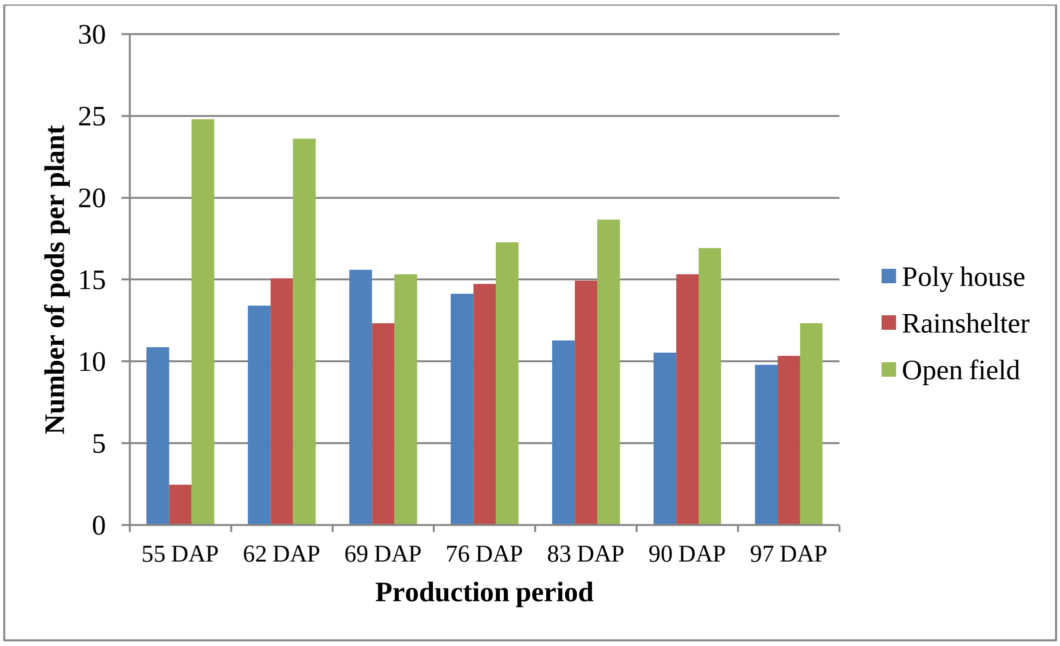

Fig 4.10 Number of pods per plant as influenced by growing environment at different stages of crop growth in cowpea

4.5.2 Average Length of Pods (cm)

The data on length of pods at different stages of crop growth as influenced by growing environment are shown in Table 4.9 and Fig 4.11. At all stages of crop growth the average length of pods inside polyhouse was superior over plants grown in open field. Also there was no significant difference in pod length between polyhouse and rainshelter. At 55, 62 and 76 DAP, the length of pods inside the rainshelter did not vary much with that from polyhouse and open field. But there was significant difference between polyhouse and open field crop. Except these three stages rainshelter crop was superior over that from open field. The greater pod length inside polyhouse and rainshelter may be due to the effect of improved microclimate like higher values of air temperature, soil temperature and humidity inside these structures. Similar results were noted by Kanthaswamy *et al*. (2000) & Gaikwad and Dumbre (2001). Also the higher plant height inside polyhouse may be attributed to the low light intensity inside the structure.

Table 4.9 Average length of pods (cm) as influenced by growing environment at different stages of crop growth in cowpea

Treatments	Average length of pods (cm)						
	55 DAP	62 DAP	69 DAP	76 DAP	83 DAP	90 DAP	97 DAP
T1-Polyhouse	50.93^{a}	53.00^{a}	53.13^{a}	51.87^{a}	52.60^{a}	50.53^{a}	52.80^{a}
T2-Rainshelter	50.13^{ab}	50.33^{ab}	51.53^{a}	49.67^{ab}	52.07^{a}	50.80^{a}	49.53^{a}
T3-Openfield	47.13^{b}	49.00^{b}	47.93^{b}	46.13^{b}	39.80^{b}	40.07^{b}	37.87^{b}

DAP – Days after planting

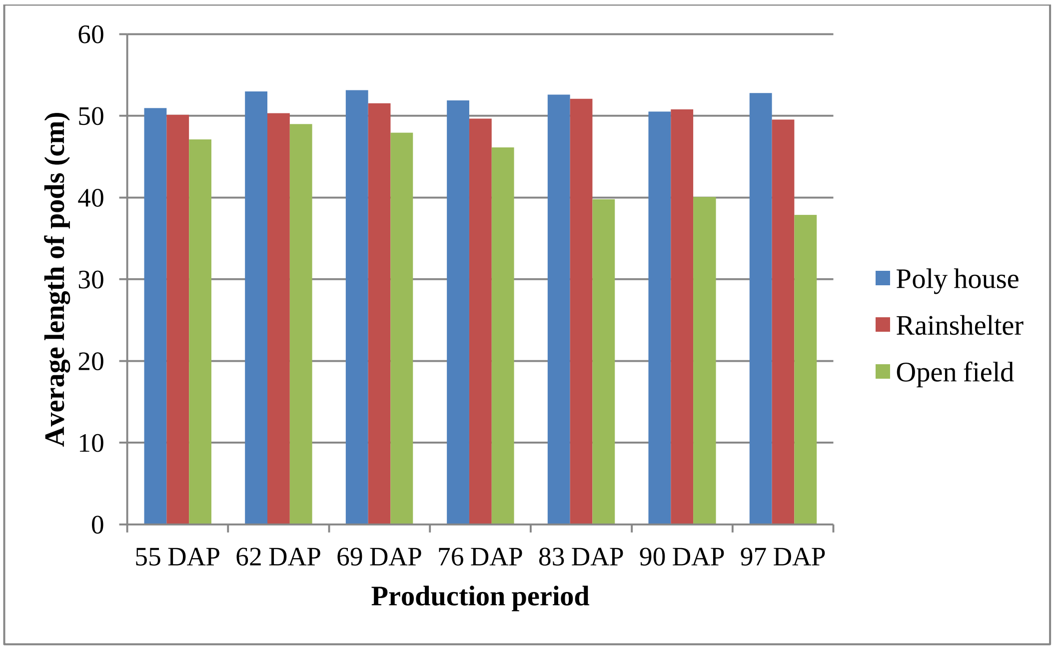

Fig 4.11 Average length of pods (cm) as influenced by growing environment at different stages of crop growth in cowpea

4.5.3 Yield per Plant (kg)

The data on yield per plant at different stages of crop growth as influenced by growing environment are shown in Table 4.10 and Fig. 4.12.

Table 4.10 Yield per plant as influenced by growing environment at different stages of crop growth in cowpea

Treatments	Yield (kg)						
	55 DAP	62 DAP	69 DAP	76 DAP	83 DAP	90 DAP	97 DAP
T1-Polyhouse	0..21[b]	0.24[b]	0.29[a]	0. 25[a]	0. 23[a]	0. 18[a]	0. 14[a]
T2-Rainshelter	0.17[b]	0.26[b]	0.23[a]	0. 25[a]	0. 21[a]	0. 18[a]	0. 17[ab]
T3-Openfield	0.37[a]	0.38[a]	0.25[a]	0.25[a]	0.23[a]	0.16[a]	0.10[b]

DAP – Days after planting

At 55 and 62 DAP, yield per plant in the open field was significantly higher than that from plants grown inside polyhouse and rainshelter. But there was no significant difference in yield between plants grown inside polyhouse and rainshelter. In the later harvests there were no significant difference in yield of cowpea grown inside polyhouse, rainshelter and open field up to 90 DAP. (Fig 4.12). At 97 DAP, yield per plant was significantly higher inside polyhouse over open field. Cowpea is a rainfed crop and the higher yield obtained from the open field than that inside protected structures during first two harvests may be because of the heavy rainfall that occurred during that month. Also the crop (Vellayani Jyothika) is an open field variety. There was no significant difference in yield inside structures and open field after first two harvests; this may be attributed to the favourable climatic conditions that prevailed under naturally ventilated polyhouse and rainshelter leading to higher vegetative growth, contributing to maximum fruit length. Similar results were obtained by Nagendra prasad (1988). Total fruit bearing period was prolonged in the polyhouse followed by rainshelter. For that reason total number of fruit harvests was more in polyhouse and rainshelter than open field. There were 10 harvests in polyhouse and rainshelter, but in the case of open field number of harvest was 8 only. This was due to the pests and deceases that affected the crop in the open field.

The total yield of cowpea obtained from the observation plants of polyhouse, rainshelter and open field were 27.23 kg, 26.38 kg and 26.30 kg respectively. From the analysis it was found that there is no significant difference in total yield of cowpea harvested from all the three treatments.

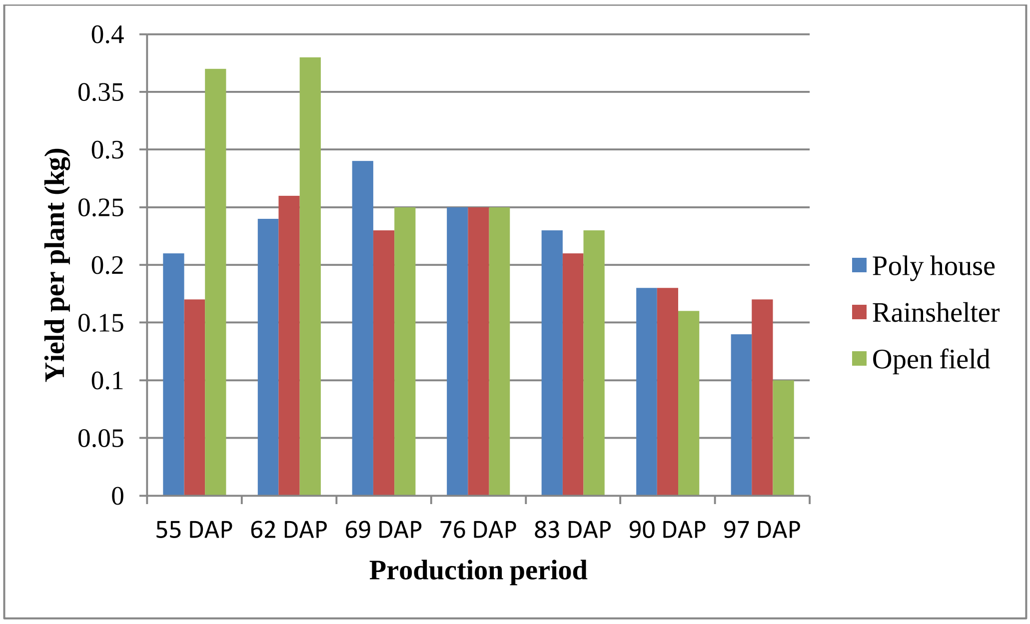

Fig 4.12 Yield per plant as influenced by growing environment at different stages of crop growth in cowpea

4.6 INCIDENCE OF PEST AND DISEASES

It was observed that incidence of pests and diseases were comparatively lower under rainshelter as compared to naturally ventilated polyhouse and open field. Higher incidence of pests and diseases were noticed in the open field. Rainfall during the growth periods might have resulted in favourable condition for diseases like anthracnose and black wine which caused heavy damage to the crop under open field. It was noted that the pests like thrips and aphids were also more under open field. This may be the reason behind reduced number of fruit harvests in open field. In polyhouse, pests like *Spodoptera litura* and mites were found which were not seen in the other two treatments. Wilting was common in all the treatments.

4.7 ECONOMICS

4.7.1 Cost economics of polyhouse

The economic analysis of a simple polyhouse was done by making the following assumptions and is tabulated below. It is assumed that 3 crops are cultivated in a year.

Assumptions

1. Expected life of the system is 15 years
2. Annual growth rate of costs and benefits is 5%
3. Salvage value is nil
4. The costs and benefits are discounted at 12%
5. Size of polyhouse: 20×5 m
6. Cost of construction of polyhouse: Rs 1100/ m^2
7. Capital cost (cost of construction + cost of irrigation system) : Rs 1200/ m^2
8. Cost of cultivation of cowpea: Rs 60/ m^2
9. Yield of cowpea: 2.45 kg/ m^2
10. Price of cowpea: Rs 30/ kg

Table 4.11 Economic analysis of polyhouse of size 20×5 m

Year	Capital Cost	O&M Cost	Production Cost	Total Cost	Benefits	Discount Factor	Present worth of Costs	Present worth of Benefits	Cash Flow	Net Present Worth
1	120000	0	18000	138000	22050	1	138000	22050	-115950	-115950
2			6300	6300	23152.5	0.893	5625	20672	16853	15047
3		6000	6615	12615	24310.13	0.797	10057	19380	11695	9323
4			6946	6946	25525.63	0.712	4944	18169	18580	13225
5			7293	7293	26801.91	0.636	4635	17033	19509	12398
6			7658	7658	28142.01	0.567	4345	15969	20484	11623
7		6946	8041	14986	29549.11	0.507	7593	14970	14563	7378
8			8443	8443	31026.56	0.452	3819	14035	22584	10216
9		0	8865	8865	32577.89	0.404	3580	13158	23713	9577
10		8041	9308	17349	34206.79	0.361	6256	12335	16858	6079
11			9773	9773	35917.13	0.322	3147	11564	26144	8418
12		0	10262	10262	37712.98	0.287	2950	10842	27451	7891
13		9308	10775	20083	39598.63	0.257	5155	10164	19516	5009
14			11314	11314	41578.56	0.229	2593	8508	30265	6936
15			11880	11880	43657.49	0.205	2431	8933	31777	6502
Total		**20986**	**141471**	**268572**	**475807**		**205129**	**217781**	**184041**	**13673**

Discount Rate (%) : 12 %

Benefit-Cost Ratio : 1.06

Net Present Worth (Rs) : 13673

4.7.2 Cost economics of rainshelter

The economic analysis of a simple rainshelter was done by making the following assumptions and is tabulated below. It is assumed that 3 crops are cultivated in a year.

Assumptions

1. Expected life of the system is 15 years
2. Annual growth rate of costs and benefits is 5%
3. Salvage value is nil
4. The costs and benefits are discounted at 12%
5. Size of rainshelter: 20×5 m
6. Cost of construction of rainshelter: Rs 650/ m^2
7. Capital cost (cost of construction + cost of irrigation system) : Rs 750/ m^2
8. Cost of cultivation of cowpea: Rs 59/ m^2
9. Yield of cowpea: 2.38 kg/ m^2
10. Price of cowpea: Rs 30/ kg

Table 4.12 Economic analysis of rainshelter of size 20×5 m

Year	Capital Cost	O&M Cost	Production Cost	Total Cost	Benefits	Discount Factor	Present worth of Costs	Present worth of Benefits	Cash Flow	Net Present Worth
1	75000	0	17700	92700	21420	1	92700	21420	-71280	-71280
2			6195	6195	22491	0.893	5531	20081	16296	14550
3		6000	6505	12505	23615.55	0.797	9969	18826	11111	8857
4			6830	6830	24796.33	0.712	4861	17650	17966	12788
5			7171	7171	26036.14	0.636	4558	16546	18865	11989
6			7530	7530	27337.95	0.567	4273	15512	19808	11240
7		6946	7907	14852	28704.85	0.507	7525	14543	13853	7018
8			8302	8302	30140.09	0.452	3755	13634	21838	9878
9		0	8717	8717	31647.1	0.404	3521	12782	22930	9261
10		8041	9153	17193	33229.45	0.361	6200	11983	16036	5783
11			9610	9610	34890.92	0.322	3094	11234	25280	8140
12		0	10091	10091	36635.47	0.287	2901	10532	26544	7631
13		9308	10596	19904	38467.24	0.257	5109	9874	18564	4765
14			11125	11125	40390.6	0.229	2550	9256	29266	6707
15			11682	11682	42410.13	0.205	2390	8678	30728	6288
Total		**30294**	**139114**	**244408**	**462213**		**158936**	**212551**	**217805**	**53614**

Discount Rate (%) : 12 %

Benefit-Cost Ratio : 1.34

Net Present Worth (Rs) : 53614

4.7.3 Cost economics of open field

The economic analysis of cowpea production in the open field of 20×5 m area with drip irrigation and trellis system was done by making the following assumptions and is tabulated below. It is assumed that 3 crops are cultivated in a year.

Assumptions

1. Expected life of the irrigation system is 12 years
2. Expected life of the wooden pole structure is 3 years
3. Annual growth rate of costs and benefits is 5%
4. Salvage value is nil
5. The costs and benefits are discounted at 12%
6. Size of plot: 20×5 m
7. Cost of construction of trellis system: Rs 40/ m^2
8. Capital cost is cost of construction + cost of irrigation system: Rs 140/ m^2
9. Cost of cultivation of cowpea: Rs 80/ m^2
10. Yield of cowpea: 2.37 kg/ m^2
11. Price of cowpea: Rs 30/ kg

Table 4.13 Economic analysis of open field of size 20×5 m

Year	Capital Cost	O&M Cost	Production Cost	Total Cost	Benefits	Discount Factor	Present worth of Costs	Present worth of Benefits	Cash Flow	Net Present Worth
1	14000	0	24000	38000	21330	1	38000	21330	-16670	-16670
2			8400	8400	22396.5	0.893	7500	19997	13997	12497
3		4000	8820	12820	23516.33	0.797	10220	18747	10696	8527
4			9261	9261	24692.14	0.712	6592	17575	15431	10984
5			9724	9724	25926.75	0.636	6180	16477	16203	10297
6			10210	10210	27223.09	0.567	5794	15447	17013	9654
7		4631	10721	15351	28584.24	0.507	7777	14482	13233	6704
8			11257	11257	30013.45	0.452	5092	13577	18757	8485
9		0	11820	11820	31514.12	0.404	4774	12728	19694	7954
10		5360	12411	17771	33089.83	0.361	6408	11933	15319	5524
11			13031	13031	34744.32	0.322	4196	11187	21713	6991
12		0	13683	13683	36481.54	0.287	3933	10488	22799	6554
Total		**13991**	**143337**	**171328**	**339512**		**106466**	**183966**	**168184**	**77501**

Discount Rate (%) : 12 %

Benefit-Cost Ratio : 1.73

Net Present Worth (Rs) : 77501

Benefit cost (B:C) ratio for each treatment was calculated with the assumption explained above. The maximum benefit cost ratio of 1.73 was noted in open field cultivation. Benefit cost ratio of polyhouse and rainshelter were 1.06 and 1.34 respectively. From the results of the study it is evident that rainshelter cultivation of cowpea is more economical than polyhouse cultivation. So under Kerala condition low cost rainshelter is more suitable than a high cost polyhouse for growing cowpea. Same result was noticed by Mathew and Anu (2011) in which it was reported that a green house with sophisticated environmental control is not very essential under Kerala condition and rainshelter is the most suitable protected cultivation structure.

CHAPTER 5

SUMMARY AND CONCLUSIONS

A study was conducted at the instructional farm of KCAET, Tavanur, Kerala, during the period from August to December 2014 to compare the performance of cowpea grown under polyhouse and rainshelter in relation to open field cultivation. The treatments comprised of three growing environments *viz.*, naturally ventilated polyhouse, rainshelter and open field. The experiment was laid out in CRD with fifteen replications. The summary of the study is presented in this chapter.

The variation of weather parameters such as maximum and minimum temperature, relative humidity, soil temperature and rainfall during the crop period was studied. The maximum temperature (39.1^{0}C) was recorded inside the naturally ventilated polyhouse during September and minimum temperature (19.6^{0}C) was recorded in the open field during December. The rise in air temperature inside the polyhouse compared to open field ranged from 2.7°C to 3.4°C. In the case of rainshelter, the rise in air temperature compared to open field was 1.4°C to 2°C. The maximum relative humidity (84.5%) was recorded during September inside the polyhouse and the minimum relative humidity (54.7%) was recorded during December in the open field. The maximum soil temperature (42^{0}C) was recorded inside the polyhouse during September and minimum soil temperature (29^{0}C) was recorded in the open field during December. Soil inside the polyhouse always maintained 3 to 5.5ºC higher temperature as compared to the soil in the open field irrespective of the growing periods of the crop. Soil inside the rainshelter maintained 0.2 to 2.6 ºC higher temperature compared to soil in the open field. The maximum rainfall (360.7 mm) was recorded during October and minimum rainfall (6.3 mm) was recorded during December.

Crop growth parameters such as plant height, internodal length, number of branches and time taken for flower initiation were noted during various crop growth stages for all the treatments.

At all growth stages, the plant height and intermodal length were significantly higher inside the polyhouse followed by rainshelter and open field. Also internodal length was significantly higher inside the rainshelter compared to the open field. The number of branches was more in open field over rainshelter and polyhouse at all growth stages. Number of branches inside rainshelter was more than that in polyhouse at 30 and 40 days after planting. Among the different treatments, early flower initiation (39 days) was recorded in the polyhouse. The late flower initiation (42 days) was noted inside the rainshelter and open field.

Yield parameters such as number of pods per plant, average length of pods and total yield per plant for each treatment were observed during various crop growth stages.

The number of pods per plant was significantly high in open field during all growth stages of growth except two stages (69 and 97 DAP). At all stages of crop growth the average length of pods inside polyhouse was superior over plants grown in the open field. Also there was no significant difference in pod length between polyhouse and rainshelter. At 55 and 62 DAP, yield per plant in the open field was significantly higher than that from plants grown inside polyhouse and rainshelter. But there was no significant difference in yield between plants grown inside polyhouse and rainshelter. In the later harvests there were no significant difference in yield of cowpea grown inside polyhouse, rainshelter and open field up to 90 DAP. There was no significant difference in total yield of cowpea harvested from all the three treatments. The total yield of cowpea recorded from polyhouse, rainshelter and open field were 27.23 kg, 26.38 kg and 26.30 kg respectively.

It was observed that incidence of pests and diseases were comparatively low inside the rainshelter as compared to naturally ventilated polyhouse and open field. Higher incidence of pests and diseases were noticed in the open field.

Benefit cost (B:C) ratio for each treatment was calculated. The maximum benefit cost ratio of 1.73 was noted in open field cultivation. Benefit cost ratio of polyhouse and rainshelter were 1.06 and 1.34 respectively.

From the study it is evident that there was no significant difference in total yield of cowpea harvested from the polyhouse, rainshelter and open field during the entire growing season. The lesser cost in case of rainshelter resulted in a higher benefit cost ratio as compared to naturally ventilated polyhouse. So cultivation of cowpea (Vellayani Jyothika) in second season is not recommended for polyhouse but recommended for rainshelter and open field. Also Incidence of pests and diseases were comparatively low inside the rainshelter and higher incidence of pests and diseases were noticed in the open field. Hence it can be concluded from the study that growing cowpea (Vellayani Jyothika) inside the rainshelter will be more profitable than growing it inside naturally ventilated polyhouse.

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Appendix I

Particle size distribution of soil inside polyhouse

Mass of dry soil sample = 1490 g

IS Sieve	Particle size(mm)	Mass retained(g)	% retained	cumulative % retained	cumulative % finer
4.75mm	4.75	318.412	21.370	21.370	78.630
2mm	2	345.321	23.176	44.546	55.454
1mm	1	228.645	15.345	59.891	40.109
600	0.6	164.565	11.045	70.936	29.064
425	0.425	61.234	4.110	75.045	24.955
300	0.3	66.314	4.451	79.496	20.504
212	0.212	207.102	13.899	93.396	6.604
150	0.15	20.152	1.352	94.748	5.252
75	0.075	31.255	2.098	96.846	3.154
Tray		46.321			

Appendix II

Particle size distribution of soil inside rainshelter

Mass of dry soil sample = 1590 g

IS Sieve	Particle size(mm)	Mass retained(g)	% retained	cumulative % retained	cumulative % finer
4.75mm	4.75	320.362	20.149	20.149	79.851
2mm	2	366.125	23.027	43.175	56.825
1mm	1	234.251	14.733	57.908	42.092
600	0.6	170.254	10.708	68.616	31.384
425	0.425	65.758	4.136	72.752	27.248
300	0.3	70.157	4.412	77.164	22.836
212	0.212	214.125	13.467	90.631	9.369
150	0.15	22.014	1.385	92.015	7.985
75	0.075	34.142	2.147	94.163	5.837
Tray		40.914			

Appendix III

Particle size distribution of soil in the open field

Mass of dry soil sample = 1620 g

IS Sieve	Particle size(mm)	Mass retained(g)	% retained	cumulative % retained	cumulative % finer
4.75mm	4.75	326.048	20.126	20.126	79.874
2mm	2	361.475	22.313	42.440	57.560
1mm	1	242.422	14.964	57.404	42.596
600	0.6	184.255	11.374	68.778	31.222
425	0.425	71.111	4.390	73.167	26.833
300	0.3	73.177	4.517	77.684	22.316
212	0.212	234.324	14.464	92.149	7.851
150	0.15	27.368	1.689	93.838	6.162
75	0.075	49.123	3.032	93.838	6.162
Tray		50.525			

COMPARATIVE EVALUATION OF NATURALLY VENTILATED POLYHOUSE AND RAINSHELTER ON THE PERFORMANCE OF COWPEA

By

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Abstract of the Thesis

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ABSTRACT

A study was conducted in the Instructional Farm of KCAET, Tavanur, Kerala, during the period from August to December 2014 to compare the performance of cowpea grown under polyhouse and rainshelter in relation to open field cultivation. Cowpea variety Vellayani Jyothika, a trailing type legume released by KAU, was used for the study. Fertilizers were applied through drip irrigation system using venturi assembly. The variation of weather parameters such as maximum and minimum temperature, relative humidity, soil temperature and rainfall during the crop growth period was studied. Mean monthly values of temperature, relative humidity and soil temperature inside the polyhouse was higher than that in rainshelter and open field throughout the growth period. The maximum rainfall (360.7 mm) was recorded in the month of October and minimum rainfall (6.3 mm) was recorded in the month of December. Crop growth parameters such as plant height, internodal length, number of branches and time taken for flower initiation were noted during various crop growth stages for all the treatments. During all growth stages, the plant height and internodal length were significantly higher inside the polyhouse followed by rainshelter and open field. Among the different treatments, early flower initiation (39 days) was noted in the polyhouse. Yield parameters such as number of pods per plant, average length of pods and total yield per plant for each treatment were noted during various crop growth stages. The number of pods per plant was significantly higher in open field. Average length of pods inside polyhouse and inside rainshelter was higher than that in the open field. There was no significant difference in total yield of cowpea harvested from the observation plants under the three treatments. The maximum Benefit Cost ratio of 1.73 was obtained in the open field cultivation. Benefit Cost ratio of polyhouse and rainshelter were 1.06 and 1.34 respectively. Incidence of pests and diseases were also comparatively low inside the rainshelter and higher incidence of pests and diseases were noticed in the open field. From the results of the study it was evident that growing cowpea (Vellayani Jyothika) inside the rainshelter is more profitable than growing it inside naturally ventilated polyhouse.