

# **EVALUATION OF CAPSICUM HYBRIDS UNDER DIFFERENT PROTECTED STRUCTURES**

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# 1. INTRODUCTION

The genus *Capsicum* (*Capsicum annuum* L.) belongs to the family Solanaceae it is grown in several parts of the world and is believed to be the native of Tropical South America (Shoemaker and Teskey, 1995). The domesticated peppers could be broadly classified into sweet and hot types based on their level of pungency. The bell pepper (*Capsicum annuum* L. var. *grossum* Sendt;  $2n = 24$ ) is commonly known as sweet pepper, capsicum or green pepper. They differ from common hot peppers in size and shape of the fruits, capsaicin content and usage. Bell pepper is one of the highly remunerative vegetables cultivated in several parts of the world especially in temperate regions of Central and South America and European countries, tropical and subtropical regions of Asian continent.

In the world, area and production of bell pepper is merged with that of hot pepper (chilli). Hence, the statistics related to pepper/chilli as whole is given. Annual world production of bell pepper in the year 2007 amounted to 27.46 million metric tonnes from an area of 1.72 million hectares. China is the major producer of capsicum and contributes 36 per cent of the worlds cultivated area with a production of 12.53 million tonnes. India contributes average annual production of 0.9 million tones from an area of 0.885 million hectare with a productivity of 1.017 tonnes per ha (Anon., 2007).

The bell pepper in India is under non-traditional category of vegetables (Kalloo and Pandey, 2002). They are mainly cultivated during *rabi* and *kharif* seasons in Karnataka, Maharashtra, Tamil Nadu, Himachal Pradesh and hilly areas of Uttar Pradesh.

Bell pepper has attained a status of high value crop in India in recent years and occupies a pride of place among vegetables in Indian cuisine because of its delicacy and pleasant flavour coupled with rich content of ascorbic acid and other vitamins and minerals. It imparts delicate taste and pleasant flavor to the cuisine. Nutritionally, bell peppers are rich in vitamins particularly vitamin A (180 IU) and vitamin C. Hundred grams of edible portion of capsicum provides 24 Kcal of energy, 1.3g of protein, 4.3 g of carbohydrate and 0.3g of fat (Anon.,2001).

It also finds place in preparations like pizza stuffing's and burger with growing popularity of fast food. The high market price it fetches is attributed to the heavy demand from the urban consumers. There is a good demand for export too. The export market needs fruits with longer shelf life, medium size tetra lobed fruits with attractive colour, mild pungency with good taste. However, the supply is inadequate due to the low productivity of the crop (Muthukrishnan *et al.*, 1986).

Basically bell pepper is a cool season tropical crop and lacks adaptability to varied environmental conditions. Despite its economic importance, growers are not in a position to produce good quality capsicum with high productivity due to various biotic (pest and diseases), abiotic (rainfall, temperature, relative humidity and light intensity) and crop factors (flower and fruit drop). Due to erratic behaviour of weather, the crops grown in open field are often exposed to fluctuating levels of temperature, humidity, wind flow etc. which ultimately affect the crop productivity adversely (Ochigbu and Harris, 1989). Besides this, limited availability of land for cultivation hampers the vegetable production. Hence, to obtain a good quality produce and production during off season, there is a need to cultivate capsicum under protected condition such as green houses or polyhouses, shadow hall, shade house, etc.

The search for new avenues has led to development to High- tech precision agricultural systems. Greenhouse, the latest word in Indian agriculture is one such means, wherein plants are grown under controlled or partially controlled environment resulting in higher yields than that is possible under open conditions (Navale *et al.*, 2003).

Growing plants under covers also helps in getting higher price for the produce, because the produce could be brought in the market when there is more demand and also when there is scarcity of the produce in the market. One can grow any plant in the temperature, humidity and light controlled greenhouses provided one knows the specific requirement of a particular plant species and technology, available for controlling and monitoring these environmental factors (Pant and Nerkar, 2003).

Greenhouses are framed structures covered with transparent or translucent material and are large enough to grow crops under partial or fully controlled environmental conditions, to obtain optimum growth and production. Greenhouses protect the crop from varied climatic conditions like wind, rainfall, excess solar radiation, extreme temperature conditions and also incidence of pests and diseases. Further, cultivation of high value, low volume crops like flowers and vegetables in greenhouse during off-season or round the year is possible with improved productivity and quality of the produce there by fetching additional returns. Hence, there is need and scope for cultivation of bell pepper under greenhouse conditions.

Different types of structures are being used for improving the productivity and profitability of horticultural crops as well as for producing planting material throughout the year like green house, shade house, mist house, etc. In modern research, green house technology can be utilized for controlling of such environmental parameters such as temperature, relative humidity, light intensity, light duration, CO<sub>2</sub> level, irrigation, nutrient supply spacing, growing medium and root development (Baghel *et al.* , 2003). The nature of growth is more of vertical due to congenial climate under cover. Hence, the plant density under protected condition is usually more. On the other hand, in order to optimize yield, a balance between vegetative (leaves and stems) and reproductive (flower and yield) growth must be established and maintained.

Protected structure is created locally by using different types of material. These structures are designed as per climatic requirements of the area for different set of environmental conditions. Growing of capsicums under cover has been reported to give good quality produce with higher productivity in several countries.

Recently, few entrepreneurs have started its cultivation under protected conditions like greenhouse, shade house, etc. to get higher productivity and quality adopting the hybrids supplied by the private companies. Now a day apart from green colour, other varieties like red, yellow, light green are also available. However, there is a need to study their performance for our conditions under greenhouse. Hence, the study on evaluation of capsicum hybrids under different structures is taken up with the following objectives;

1. To study the performance of capsicum hybrids under protected structures.
2. To study the influence of different growing environments on productivity and quality of the produce.
3. To work out cost economics of growing capsicum hybrids under different protected structures.

## 2. REVIEW OF LITERATURE

Capsicum is one of the most important nutritious and highly remunerative vegetable crops grown mainly for its green fruits. It is difficult to obtain higher yields of good quality fruits throughout the year under open conditions in most parts of India, as it is delicate crop. Cultivation of bell pepper is possible even during the off-season under protected structures. Agronomical practices play an important role for obtaining higher yields especially under greenhouse structures. Newly evolved and superior type of varieties/hybrids of crops needs to be assessed for their optimum density of planting and other cultural practices to achieve maximum yields both under open and protected structures. The literature pertaining to the performance of capsicum and other related vegetables under different protected structures is reviewed under here.

### 2.1 Performance of capsicum hybrids and other vegetable crops under protected structures

#### 2.1.1 Capsicum

Maurer (1981) reported that in the off-season or in the extended season among the 28 bell pepper cultivars cultivated under partially environment controlled greenhouse, cultivars 'Newace' and 'Early prolific' produced higher yields of 4.2 kg and 3.5 kg per plant respectively, compared to all the other varieties.

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 non significant effect on fruit shape and maturity.

Buczowska. (1990) studied the sweet capsicum cropping in unheated structures. Fruit production by five cultivars in glasshouse and in a plastic tunnel was investigated over three years. Temperatures in the two structures were higher than in the open during May-September and growing conditions, especially in the tunnel, were better. Annual weather conditions affected both yield and quality. Yield and quality data for all cultivars in both environments were tabulated. The highest total yield and the highest percentage of marketable fruit were produced in both structures by the Czechoslovaks cultivar PCR. Fruit vitamin C, carbohydrates and dry matter contents varied with cultivar, but were not affected marketedly by the season.

Choe *et al.* (1991) studied that application of three levels of rice straw, 0.5, 1.0 and 1.5 tons per 10 hectare, with or without an extra application of nitrogen at 6 kg per ton of straw, was compared with application of compost and chemical fertilizer only in terms of soil improvement effect. The soil physical properties such as bulk density and porosity were improved, and the change in microbial flora around the root zone was better with rice straw application than with compost only. Carbon dioxide production also increased with more straw application.

Gomez. (1994) conducted a comparative study among capsicum cultivars planted on 2<sup>nd</sup> 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 cv. Fiuco (16,268 kg/ha) in the first harvest; in this harvest Elisa and Fiuco yielded 6738 and 3417 kg/ha, respectively.

Abou-Hadid *et al* (1994) worked on the soil less culture of *Capsicum annuum* cv. Delphine F<sub>1</sub> in controlled greenhouse conditions using the nutrient film technique (NFT) and rockwool between January and September 1991. Plants grown in NFT produced higher total yields than those in rockwool (4.47 and 3.93 kg/plant, respectively). There was, however, no

difference in plant height and leaf number. NFT was more profitable than rock wool, largely due to the extra cost of the rockwool slaps.

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 F<sub>1</sub> growing in polyhouse, while it was only ten days in fruits produced in open condition.

## 2.1.2 Other vegetables

### Tomato

Wajaszek *et al.* (1979) reported enrichment of CO<sub>2</sub> (1500ppm) under greenhouse increased yields (45.2%) of tomato as compared to normal atmosphere.

Mecay and Janes (1983) stated that tomato gave 75% higher yield (33.7 kg/m<sup>2</sup>) from Sodium fluorescent lamps as source of light compared to natural radiation(19.13 kg/m<sup>2</sup>) and total yield (9.4 kg/m<sup>2</sup>) was markedly improved as compared to open conditions (6.6 & 7.35 kg/m<sup>2</sup>, respectively) (Ohigbu and Harris, 1989).

Under polyethylene greenhouse condition, maximum yield of ripe tomato fruits (8.6 kg/ m<sup>2</sup>) and total yield (9.4 kg/ m<sup>2</sup>) was obtained as compared to open conditions (6.6 kg/ m<sup>2</sup> and 7.35 kg/ m<sup>2</sup>, 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).

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.

### Cucumber

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

Mohamedien *et al.* (1991) reported that the cucumber cv. Farid under polyhouse conditions gave maximum fruit weight (114.249g), fruit length (15.69 cm), diameter (3.3 cm) and yield (75.07 kg/plot) as compared to other cultivars.

## 2.2 Influence of different growing environment on productivity and quality of the produce

### 2.2.1 Capsicum

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°C and were largest when plants exposed to low temperature at four leaf stage.

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

Polowick and Sawahaney (1985) reported that, the low temperatures (18/15°C) had more effect (negative response) on flowers and fruits of capsicum than intermediate (23/18°C) temperatures.

Gosselin and Trudel (1986) observed maximum shoot dry weight and leaf area at root zone temperatures of 24°C and 30°C in pepper. While, maximum fruit weight and number occurred at 30°C root zone temperature. Highest temperature (25°C) 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<sup>2</sup>) in sweet pepper were greatest at daily mean temperature of 21-21.3°C.

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).

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.

Chen *et al.* (1994) showed that sweet pepper (*Capsicum frutescens*) fruits exposed to chilling stress (0.1°C) 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°C until the end of vegetative growth and about 13°C during flowering) increased yield and advanced the harvesting time of peppers.

## 2.2.2 Other Vegetables

### Tomato

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°C.

Dekoning (1992) reported that total yield in tomato was significantly higher at the higher night temperature (18.6°C) than at low night temperature (16.3°C). 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°C) (Malfa, 1993).

### Cucumber

Vooren (1980) reported that increasing night temperature from 12°C to 20°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°C air and 25°C root temperature. With the lowest night temperature (9°C) after planting there was a delay in growth, poor elongation of laterals and reduction in total cucumber yield (Yamashita *et al.*, 1984).

Shi *et al.* (1991) noticed the highest net photosynthetic rate at 30°C when plants were at an early growth stage and at 35°C during mid late growth stage and at 35°C large quantities of assimilates were transported to vegetative parts in cucumber plant.

Marcellis (1993) reported that total leaf area and leaf weight per plant were greater at 25°C than at 18°C in cucumber.

Okra

At higher night temperature (36/27°C) maximum taller plants were observed in Okra cultivars (Tenka and Ormrdo, 1985).

## 2.3 Cost economics

Khan (1995) reported that though 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.

### 2.3.1 Capsicum

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.

Granges and Leger (1989) found that by increasing the plant density of capsicum from normal level of three plants per m<sup>2</sup> to six plants per m<sup>2</sup>, 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 spacings (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 gave relatively lower yield due to lower plant population excellent quality fruits were obtained. Medium spacing of 45 x 30 cm gave the highest net returns of Rs. 21,018/ 100m<sup>2</sup>/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<sup>2</sup>/ year) with least cost benefit ratio of 1: 1.65 (@ of Rs. 16/kg) (Nagendra Prasad, 2001)

### 2.3.2 Other crops

Hoon and Van der (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 Opel (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 is more economical than for one year.

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



$$\begin{aligned} T_{10} &= \text{SHWM} + H_1 \\ T_{11} &= \text{SHWM} + H_2 \\ T_{12} &= \text{SHWM} + H_3 \end{aligned}$$

## 3.2 Experimental Procedure

The crop was grown in different structures by adopting the recommended package of practices according to the different growing structures.

## 3.3 Characters of capsicum hybrids

Orobelle (yellow), Bomby (red) and Indra (green) F<sub>1</sub> hybrids were developed by Syngenta India Limited Company. These hybrids were said to have early fruit bearing character, with highest yield during initial 2 to 3 pickings.

### 3.3.1 Preparation of land in protected structures and fumigation

Land area inside the protected structure was thoroughly dug to a depth of 20 to 25 cm, One month prior to planting weeds and stubbles were removed completely and the soil was brought to a fine tilth. The beds of convenient size (length 31.5 m, width 1m and height 15 cm) were prepared out of mixture of red soil + farmyard manure + coco peat + sand + paddy husk in 1:1:1:1 proportion + vermicompost (1 kg/m<sup>2</sup>) and neem cake (200 g/m<sup>2</sup>). Soil was disinfected with Formalin (2%) to overcome the problem of soil borne diseases. Immediately after treating the soil with Formalin the area was covered with black polythene sheet for 3-4 days, thereafter the polythene sheet was removed and irrigated twice to remove chemical residues if any in the soil. Raised beds of 30 cm height, 35 m length and 30 meter width were prepared leaving 50 cm between the beds to enable easy cultural operations like weeding, spraying and harvesting etc.

Misting was carried out with the help of overhead misters twice a day in summer months and completely stopped during rainy days.

### 3.3.2 Mulching

To conserve the soil moisture and prevent weed growth, beds were covered with silver coloured mulch having 30 micron thickness.

### 3.3.3 Planting

One month old seedlings were transplanted under protected structures according to the treatment spacing of, 45x60 cm. The holes were made on each mark by using PVC pipe. Before transplanting, the seedlings were dipped in 0.2% bavistin and 2% superphosphate solution for two minutes and were transplanted.

### 3.3.4 Fertilizer Application

Fertilizers were provided with the help of automatic computerized injector

Initial 11/2 month : 1:2:5                      N:P:K were applied

Next onwards : 2:1:3                              N:P:K were applied on alternate days

Weekly foliar application of micronutrients was provided

### 3.3.5 Weeding and plant protection measures.

Mulching was done to reduce weed problem in the beds. Only the space between the beds was kept free by manual weeding.

• Plant protection

Sl. No.	Pest	Scientific Name	Common name	Trade name
1.	Thrips	<i>Scirtothrips dorsalis</i>	Imidacloprid 17.8 SC	Confidor 0.05 %
2.	Mites	<i>Polyphagotarsonemus latus</i>	Abamectin 1.9 EC	Vertimec 0.03 %
3.	Fruit borer	<i>Spodoptera litura</i>	Methomyl 40 SP	Lannate 0.2 %

Sl. No.	Disease	Common name	Trade name
1.	Dieback	Propiconazole 25EC	Tilt 0.1 %
2.	Powdery mildew	Penconazole 10EC	Topaz 0.05%
3.	Fruit rot	Metalaxyl + Mancozeb72 WP (8%) (64%)	Ridomyl MZ 0.2%
4.	Sclelotium rot	Carboxin 75 WP	Vitavax 0.2 %

### 3.3.6 Irrigation

The plants were irrigated one hour daily with drip irrigation system. Plants were watered before 12 noon or late evening.

### 3.3.7 Harvesting

Fully mature fruits at 10-20 % colour break stage were harvested periodically with the help of secature. Cleaning, sorting and grading operations were carried out and then packed in corrugated card board boxes before sending to market.

## 3.4 Observations

### 3.4.1 Vegetative parameters

#### 3.4.1.1 Plant height (cm)

Five plants were tagged at random in each treatment for recording the plant height at an interval of 30 days starting from the date of transplanting. The plant height was measured from the ground level to the growing tip of the main stem at 30, 60, 90 and 120 days after transplanting (DAP). The average height was calculated and expressed in centimeters.

#### 3.4.1.2 Number of leaves per plant

Well developed leaves were counted at 30, 60, 90 and 120 days after planting from all the plants tagged for recording observations and the mean of number of leaves per plant was worked out.



Naturally ventilated poly house



Shadow hall



Shade house with misting



Shade house without misting

**Plate 1: Over view of different growing structures**



Naturally ventilated poly house



Shadow hall



Shade house with misting



Shade house without misting

**Plate 2: General view of the experimental site**

#### 3.4.1.3 Time taken for flower initiation

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

#### 3.4.1.4 Time required for first harvest

Individual flowers were tagged and the same fruits were harvested at maturity by recording the date of harvest and number of days were counted and recorded.

### 3.4.2 Reproductive parameters

#### 3.4.2.1 Number of flowers per plant

Fully opened flowers were counted at 60, 90, 120 and 180 days from each tagged plant and recorded.

#### 3.4.2.2 Number of fruits per plant

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

#### 3.4.2.3 Per cent fruit set

Ten unopened buds were tagged at random in each of the plant under observation. The number of fruits set from the tagged buds was recorded periodically and per cent fruit set was calculated.

$$\text{Per cent fruit set (\%)} = \frac{\text{Number of fruits set}}{\text{Number of flowers tagged}} \times 100$$

### 3.4.3 Quality parameters

#### 3.4.3.1 Individual fruit weight (g)

The fresh capsicum fruits harvested from the labeled plants from each treatment were weighed and recorded in grams.

#### 3.4.3.2 Fruit volume (cc)

Five fruits were randomly selected from each plant under observation and the volume of fruit was recorded by dipping the fruits individually in to a jar containing water and the excess over flowed water measured using a measuring cylinder and the mean was calculated and expressed in cubic centimeters (cc).

#### 3.4.3.3 Rind thickness (cm)

The selected fruits were sliced at the equatorial plane to measure the rind thickness with the help of vernier calipers and the mean as computed was recorded in mm.

#### 3.4.3.4 Shelf life (days)

Fully mature fruits were harvested from each treatment and they were kept under ambient conditions and the number of days were counted until the fruits remain fresh and at acceptable quality. The number of days was calculated to express the shelf life in days were counted and recorded.

### 3.4.4 Yield parameters

#### 3.4.4.1 Fruit yield per plant (kg)

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

#### 3.4.4.2 Fruit yield per ha (ton)

The weight of mature fruits harvested from each picking in tagged plants in each replication was recorded till final harvest and the total yield of fruits per hectare was computed and expressed in tones per hectare.

### 3.4.5 Environmental parameters

Following environmental parameters were recorded from the time of transplanting to that of last picking of fruits in both inside the structure and outside the structure.

#### 3.4.5.1 Temperature (°C)

Air temperature inside the protected structure and outside the structure was recorded by using Thermo hygrometer at weekly interval, and expressed as mean monthly data.

#### 3.4.5.2 Relative humidity (%)

The relative humidity inside and outside the protected structure was recorded by using Thermo hygrometer at weekly interval, and expressed as mean monthly data.

#### 3.4.5.3 Light intensity(klux)

The light intensity inside the protected structure and outside the structure was recorded with the help of Luxmeter and recorded the data in klux. and expressed as mean monthly data.

## 3.5 Economics

Economics of capsicum production under different protected structures was worked out by considering the present price of inputs and produce.

$$\text{Net returns (Rs.ha}^{-1}\text{)} = \text{Gross returns (Rs.ha}^{-1}\text{)} - \text{cost of cultivation (Rs.ha}^{-1}\text{)}$$

$$\text{Benefit: Cost ratio} = \frac{\text{Net returns (Rs.ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs.ha}^{-1}\text{)}}$$

## 3.6 Statistical analysis

The data pertaining to vegetative, reproductive, quality and yield characters were tabulated treatment and replication wise. The data statistically analyzed by software MSTAT-C. Fisher and Yates tables (1957) were referred for knowing the tabulated values at five per cent level of significance at corresponding degree of freedom. Inferences were drawn as revealed by the analysis of tables.

## 4. EXPERIMENTAL RESULTS

The experimental results obtained from the present study on “Evaluation of capsicum hybrids under protected structures” are furnished here, under the following sub-headings.

### 4.1 Vegetative characters

#### 4.1.1 Plant height (cm)

The data on plant height at different stages of crop growth as influenced by growing structures, hybrids in capsicum and their interactions are presented in Table 1.

The plant height of capsicum differed significantly due to growing structures, hybrids and their interactions at all stages of crop growth viz., 30, 60, 90 and 120 days after planting (DAP).

At 30 DAP, among the different structures, plant height was maximum (50.11 cm) in polyhouse, which was significantly superior over the other three growing structures. The least plant height (43.38 cm) was recorded under shade house without misting.

Among the three hybrids, Orobelle recorded the maximum plant height (50.41 cm) which was significantly superior over the other two hybrids. Orobelle was followed by Indra (46.16 cm) and the least plant height was recorded by Bomby (43.91 cm).

With respect to the interactions between the growing structures and hybrids at 30 DAP the highest plant height (54.33 cm) was recorded by Orobelle grown under polyhouse ( $S_1H_1$ ) which was on par with Orobelle grown under shadow hall (54.00 cm) ( $S_2H_1$ ) and Indra grown under polyhouse (50.00 cm) ( $S_1H_3$ ).

Among the interactions, the least plant height (41.16 cm) was recorded by Bomby grown under shade house without misting ( $S_4H_2$ ) closely followed by Bomby grown under shade house with misting ( $S_3H_2$ ) and Indra grown under shade house without misting ( $S_4H_3$ ) and all these three were statically on par with each other. A similar trend was noticed at 60 DAP and 90 DAP as that of 30 DAP.

At 120 DAP, among the different structures, plant height was maximum (155.73 cm) under polyhouse, which was significantly superior over the other growing structures. The least plant height (125.44 cm) was recorded under shade house without misting.

Among the three hybrids, Orobelle recorded the maximum plant height (157.75 cm) which was significantly superior over the other two hybrids. It was followed by Indra (132.62) and the least plant height was recorded by Bomby (130.62 cm).

With respect to the interactions, the highest plant height (145.00 cm) was recorded by Orobelle grown under polyhouse ( $S_1H_1$ ) which was on par with Orobelle (142.11 cm) grown under shadow hall ( $S_2H_1$ ) and followed by Indra (140.00 cm) grown under polyhouse ( $S_1H_3$ ).

Among the interactions, the least plant height (129.13 cm) was recorded by Bomby grown under shade house without misting ( $S_4H_2$ ), which was closely followed by Indra grown under shade house without misting (129.17 cm) ( $S_3H_2$ ) and Indra grown under shade house with misting (130.00 cm) ( $S_3H_3$ ). These three were statistically on par with each other.

#### 4.1.2 Number of leaves per plant

The data on number of leaves per plant at different stages of crop growth as influenced by growing structures, hybrids in capsicum and their interactions are presented in Table 2.

**Table 1: Plant height (cm) as influenced by growing structures and hybrids at different stages of crop growth in capsicum**

Treatment	Plant height (cm)			
	30 DAP	60 DAP	90 DAP	120 DAP
<b>A. Growing structure</b>				
S <sub>1</sub> – Polyhouse	50.11	78.61	108.27	155.73
S <sub>2</sub> – Shadow hall	48.27	73.33	105.50	136.38
S <sub>3</sub> – Shade house with misting	45.55	67.88	105.05	133.38
S <sub>4</sub> – Shade house without misting	43.38	67.66	93.16	125.44
SE m <sub>±</sub>	0.485	0.820	0.865	0.891
CD (P=0.05)	1.678	2.837	2.993	3.083
<b>B. Hybrid</b>				
H <sub>1</sub> – Orobelle (yellow)	50.41	75.25	106.83	157.75
H <sub>2</sub> – Bomby (red)	43.91	68.33	100.95	130.62
H <sub>3</sub> – Indra (green)	46.16	72.04	101.20	132.62
SE m <sub>±</sub>	0.546	0.608	0.668	0.681
CD (P=0.05)	2.143	2.387	2.622	2.673
<b>C. Interaction</b>				
S <sub>1</sub> H <sub>1</sub>	54.33	83.66	118.00	145.00
S <sub>1</sub> H <sub>2</sub>	46.00	74.50	100.33	130.16
S <sub>1</sub> H <sub>3</sub>	50.00	77.66	106.50	140.00
S <sub>2</sub> H <sub>1</sub>	54.00	83.65	115.00	142.11
S <sub>2</sub> H <sub>2</sub>	45.13	69.33	100.66	130.20
S <sub>2</sub> H <sub>3</sub>	45.83	67.00	100.83	130.21
S <sub>3</sub> H <sub>1</sub>	48.00	60.66	107.00	132.11
S <sub>3</sub> H <sub>2</sub>	43.50	73.66	108.66	140.00
S <sub>3</sub> H <sub>3</sub>	45.16	60.00	99.50	130.00
S <sub>4</sub> H <sub>1</sub>	45.33	73.00	95.16	136.00
S <sub>4</sub> H <sub>2</sub>	41.16	59.33	87.33	129.13
S <sub>4</sub> H <sub>3</sub>	43.66	60.66	95.16	129.17
SE m <sub>±</sub>	0.862	1.225	1.061	1.213
CD (P=0.05)	5.312	3.770	3.269	3.730

DAP – Days after planting

**Table 2: Number of leaves per plant as influenced by growing structures and hybrids at different stages of crop growth in capsicum**

Treatment	Number of leaves per plant			
	30 DAP	60 DAP	90 DAP	120 DAP
<b>A. Growing structure</b>				
S <sub>1</sub> – Polyhouse	52.16	68.94	85.00	110.27
S <sub>2</sub> – Shadow hall	49.61	65.38	78.33	101.55
S <sub>3</sub> – Shade house with misting	46.44	60.50	73.61	95.44
S <sub>4</sub> – Shade house without misting	44.22	58.16	66.83	86.11
SE m $\pm$	0.231	0.151	0.652	0.231
CD (P=0.05)	0.799	0.522	2.256	0.737
<b>B. Hybrid</b>				
H <sub>1</sub> – Orabelle (yellow)	50.62	64.66	77.66	103.83
H <sub>2</sub> – Bomby (red)	48.20	63.08	77.41	101.45
H <sub>3</sub> – Indra (green)	45.50	62.00	72.75	95.75
SE m $\pm$	0.247	0.224	0.282	0.140
CD (P=0.05)	0.969	0.879	1.107	0.549
<b>C. Interaction</b>				
S <sub>1</sub> H <sub>1</sub>	54.33	78.11	90.00	125.00
S <sub>1</sub> H <sub>2</sub>	46.00	63.00	76.00	99.16
S <sub>1</sub> H <sub>3</sub>	50.50	65.50	77.83	101.16
S <sub>2</sub> H <sub>1</sub>	48.50	67.26	80.33	120.33
S <sub>2</sub> H <sub>2</sub>	52.33	70.33	89.66	120.33
S <sub>2</sub> H <sub>3</sub>	51.00	68.16	81.16	110.50
S <sub>3</sub> H <sub>1</sub>	48.50	61.66	72.33	100.16
S <sub>3</sub> H <sub>2</sub>	45.51	59.50	68.33	89.00
S <sub>3</sub> H <sub>3</sub>	44.33	60.33	80.16	89.00
S <sub>4</sub> H <sub>1</sub>	47.33	59.00	67.16	90.50
S <sub>4</sub> H <sub>2</sub>	42.00	57.33	67.00	78.83
S <sub>4</sub> H <sub>3</sub>	43.33	58.16	66.33	81.00
SE m $\pm$	0.442	0.339	1.017	0.471
CD (P=0.05)	1.361	1.044	3.133	1.451

DAP – Days after planting

The number of leaves per plant differed significantly due to growing structures, different hybrids and their interactions at all stages of crop growth viz. 30, 60, 90 and 120 days after planting (DAP).

At 30 DAP, among the different structures, number of leaves per plant was maximum (52.16) under polyhouse which was significantly superior over the other growing structures. The least number of leaves per plant (44.22) was recorded under shade house without misting.

Among the three hybrids, Orobelle recorded the maximum (50.62) number of leaves per plant which was significantly superior over the other two hybrids. It was followed by Bomby (48.20) and the least number of leaves per plant was recorded by Indra (45.50).

With respect to the interactions, the highest number of leaves per plant (54.33) was recorded by Orobelle grown under polyhouse ( $S_1H_1$ ) closely followed by Bomby (52.33) grown under shadow hall ( $S_2H_2$ ) and Indra (51.00) grown under shadow hall ( $S_2H_3$ ).

Among the interactions, the least number of leaves per plant (42.00) was recorded by Bomby grown under shade house without misting ( $S_4H_2$ ) which was on par with Indra grown under shade house without misting ( $S_4H_3$ ) and followed by Indra grown under shade house with misting ( $S_3H_3$ ). The similar trend was observed at 60 and 90 DAP.

At 120 DAP, among the different structures, number of leaves per plant was maximum (110.27) under polyhouse, which was significantly superior over the other growing structures. The least number of leaves per plant (86.11) was recorded under shade house without misting.

Among the three hybrids, Orobelle recorded the maximum number of leaves per plant (103.83) which was significantly superior over the other two hybrids. Orobelle was followed by Bomby (101.45) and the least number of leaves per plant was recorded by Indra (95.75).

With respect to the interactions, the highest number of leaves per plant (125.00) was recorded by Orobelle grown under polyhouse ( $S_1H_1$ ) closely followed by Bomby grown under shadow hall (120.33) ( $S_2H_2$ ) and Orobelle grown under shadow hall (120.33) ( $S_2H_3$ ).

Among the interactions, the least number of leaves per plant (78.83) was recorded by Bomby grown under shade house without misting ( $S_4H_2$ ) closely followed by Indra grown under shade house without misting ( $S_4H_3$ ) and Indra grown under shade house with misting ( $S_3H_3$ ).

#### 4.1.3 Time taken for flower initiation

The data on time taken for flower initiation as influenced by growing structures, hybrids in capsicum and their interactions are presented in Table 3.

Among the different structures, early flower initiation (33.00 days) was recorded under polyhouse which was significantly superior over the other growing structures. The late flower initiation (40.68 days) was recorded under shadow hall.

Among the three hybrids, Indra recorded early (35.42 days) flower initiation which was significantly superior over the other two hybrids. Indra was followed Bomby (36.20 days) and Orobelle (38.40 days).

With respect to the interactions, the early flower initiation (30.66 days) was recorded by Indra grown under polyhouse ( $S_1H_3$ ) closely followed by Bomby (33.66 days) grown under shade house with misting ( $S_3H_2$ ) and Orobelle grown under shade house without misting ( $S_4H_1$ ) (34.66 days).

Among the interactions, the highest number of days for flower initiation (43.06 days) was recorded by Orobelle grown under shadow hall ( $S_2H_1$ ) closely followed by Bomby grown under shade house without misting ( $S_4H_2$ ) (41.00 days) and Indra grown under shadow hall ( $S_2H_3$ ) (40.00 days).

**Table 3: Time taken for different growth attributes as influenced by growing structures and hybrids in capsicum**

Treatment	Time taken for flower initiation (days)	Time taken for first harvest (days)
<b>A. Growing structure</b>		
S <sub>1</sub> – Polyhouse	33.00	86.00
S <sub>2</sub> – Shadow hall	40.68	87.22
S <sub>3</sub> – Shade house with misting	35.95	86.33
S <sub>4</sub> – Shade house without misting	36.50	86.55
SE m <sub>±</sub>	0.141	0.262
CD (P=0.05)	0.487	0.908
<b>B. Hybrid</b>		
H <sub>1</sub> – Orabelle (yellow)	38.40	87.08
H <sub>2</sub> – Bomby (red)	36.20	86.50
H <sub>3</sub> – Indra (green)	35.42	86.00
SE m <sub>±</sub>	0.110	0.201
CD (P=0.05)	0.396	0.425
<b>C. Interaction</b>		
S <sub>1</sub> H <sub>1</sub>	39.00	87.00
S <sub>1</sub> H <sub>2</sub>	38.10	87.23
S <sub>1</sub> H <sub>3</sub>	30.66	85.33
S <sub>2</sub> H <sub>1</sub>	43.06	89.00
S <sub>2</sub> H <sub>2</sub>	34.83	86.33
S <sub>2</sub> H <sub>3</sub>	40.00	81.33
S <sub>3</sub> H <sub>1</sub>	38.19	86.20
S <sub>3</sub> H <sub>2</sub>	33.66	86.00
S <sub>3</sub> H <sub>3</sub>	35.03	86.66
S <sub>4</sub> H <sub>1</sub>	34.66	86.10
S <sub>4</sub> H <sub>2</sub>	41.00	88.13
S <sub>4</sub> H <sub>3</sub>	37.00	86.73
SE m <sub>±</sub>	0.247	0.286
CD (P=0.05)	0.761	0.881

#### 4.1.4 Time required for first harvest

The data on time required for first harvest as influenced by growing structures, hybrids in capsicum and their interactions are presented in Table 3.

Among the different structures, early harvesting (86.00 days) was recorded under polyhouse which was on par with shade house with misting and shade house without misting. The late harvesting (87.22 days) was recorded under shadow hall.

Among the three hybrids, Indra recorded the earliest harvesting (86.00 days) which was significantly superior over the other two hybrids. Indra was followed by Bomby (86.50 days) and Orobelle (87.08 days).

With respect to the interactions, the early harvesting (81.33 days) was recorded by Indra grown under shadow hall ( $S_2H_3$ ) closely followed by Indra grown under polyhouse ( $S_1H_3$ ) (85.33 days) and Bomby grown under shade house with misting ( $S_3H_2$ ) (86.00 days).

Among the interactions, the latest harvesting (89.00 days) was recorded by Orobelle grown under shadow hall ( $S_2H_1$ ) closely followed by Bomby grown under shade house without misting ( $S_4H_2$ ) (88.13 days) and Bomby grown under polyhouse ( $S_1H_2$ ) (87.23 days).

## 4.2 Reproductive parameters

### 4.2.1 Number of flowers per plant

The data on number of flowers per plant at different stages of crop growth as influenced by growing structures, hybrids in capsicum and their interactions are presented in Table 4.

The number of flowers per plant differed significantly due to growing structures and hybrids and their interactions at all stages of crop growth *viz.*, 60, 90, 120 and 180 days after planting (DAP).

At 60 DAP, among the different structures, number of flowers per plant was maximum (7.61) under polyhouse, which was significantly superior over the other growing structures. The least number of flowers per plant (3.83) was recorded under shadow hall.

Among the three hybrids, Indra recorded the maximum (7.04) number of flowers per plant which was significantly superior over the other two hybrids. Indra was followed by Orobelle (5.82) and the least number of flowers was recorded by Bomby (5.20).

With respect to the interactions, the highest number of flowers per plant (9.00) was recorded by Indra grown under polyhouse ( $S_1H_3$ ) closely followed by Orobelle grown under shade house with misting ( $S_3H_1$ ) (7.16) and Indra grown under shade house with misting ( $S_4H_2$ ) (7.00).

Among the interactions, the least number of flowers per plant (2.83) was recorded by Bomby grown under shadow hall ( $S_2H_2$ ) closely followed by Orobelle grown under shadow hall ( $S_2H_1$ ) (3.66) and Bomby grown under shade house with misting ( $S_3H_2$ ) (5.00).

At 120 DAP, among the different structures, number of flowers per plant was maximum (12.44) under polyhouse, which was significantly superior over the other growing structures. The least number of flowers per plant (10.22) was recorded under shadow hall.

Among the three hybrids, Indra recorded the maximum number of flowers per plant (13.41) which was significantly superior over the other two hybrids. Indra was followed by Orobelle (11.45) and the least number of flowers per plant was recorded by Bomby (10.87).

With respect to the interactions, the highest number of flowers per plant (14.66) was recorded by Indra grown under polyhouse ( $S_1H_3$ ) closely followed by Bomby grown under shade house with misting ( $S_3H_2$ ) (14.33) and Orobelle grown under polyhouse ( $S_1H_1$ ) (12.66).

**Table 4: Number of flowers per plant as influenced by growing structures and hybrids at different stages of crop growth in capsicum**

Treatment	Number of flowers per plant				
	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP
<b>A. Growing structure</b>					
S <sub>1</sub> – Polyhouse	7.61	11.88	12.44	6.72	3.05
S <sub>2</sub> – Shadow hall	3.83	7.88	10.22	5.61	2.11
S <sub>3</sub> – Shade house with misting	6.55	10.72	11.55	6.66	3.00
S <sub>4</sub> – Shade house without misting	6.16	10.22	11.10	6.05	2.91
SE m <sub>±</sub>	0.156	0.169	0.182	0.146	0.126
CD (P=0.05)	0.539	0.584	0.629	0.505	0.436
<b>B. Hybrid</b>					
H <sub>1</sub> – Orobelle (yellow)	5.82	10.12	11.45	6.50	3.01
H <sub>2</sub> – Bomby (red)	5.20	8.83	10.87	5.62	2.08
H <sub>3</sub> – Indra (green)	7.04	11.58	13.41	6.66	3.25
SE m <sub>±</sub>	0.221	0.063	0.091	0.055	0.022
CD (P=0.05)	0.863	0.247	0.357	0.215	0.086
<b>C. Interaction</b>					
S <sub>1</sub> H <sub>1</sub>	6.83	11.00	12.66	6.33	3.66
S <sub>1</sub> H <sub>2</sub>	6.00	11.12	10.00	6.35	2.11
S <sub>1</sub> H <sub>3</sub>	9.00	13.66	14.66	7.33	4.16
S <sub>2</sub> H <sub>1</sub>	3.66	8.00	10.20	5.66	1.33
S <sub>2</sub> H <sub>2</sub>	2.83	6.50	8.83	5.00	1.66
S <sub>2</sub> H <sub>3</sub>	5.16	9.16	10.00	6.16	2.00
S <sub>3</sub> H <sub>1</sub>	7.16	11.50	11.60	7.16	4.00
S <sub>3</sub> H <sub>2</sub>	5.00	8.83	14.33	6.00	2.66
S <sub>3</sub> H <sub>3</sub>	6.13	11.83	11.00	7.00	2.50
S <sub>4</sub> H <sub>1</sub>	6.16	10.00	10.66	6.83	3.33
S <sub>4</sub> H <sub>2</sub>	7.00	9.00	11.60	5.16	3.66
S <sub>4</sub> H <sub>3</sub>	6.15	9.12	10.20	6.16	2.81
SE m <sub>±</sub>	0.277	0.356	0.857	0.181	0.165
CD (P=0.05)	0.853	0.961	2.640	0.557	0.508

DAP – Days after planting

Among the interactions, the least number of flowers per plant (8.83) was recorded by Bomby grown under shadow hall ( $S_2H_2$ ) closely followed by Indra grown under shadow hall ( $S_2H_3$ ) (10.00) and Bomby grown under shadow hall ( $S_1H_2$ ) (10.00). All these, three were statistically on par with each other.

#### 4.2.2 Per cent fruit set

The data on per cent fruit set as influenced by growing structures, hybrids in capsicum and their interactions are presented in Table 5.

Among the different structures, maximum fruit set (49.81) was recorded under polyhouse which was significantly superior over the other growing structures. The minimum fruit set (32.76) was recorded under shadow hall.

Among the three hybrids, Indra recorded maximum fruit set (45.45) which was significantly superior over the other two hybrids. Indra was followed by Orobelle (42.36) and Bomby (41.17).

With respect to the interactions, the maximum fruit set (52.75) was recorded by Indra grown under polyhouse ( $S_1H_3$ ) closely followed by Orobelle grown under shade house with misting ( $S_3H_1$ ) (49.81) and Bomby grown under shade house without misting ( $S_4H_2$ ) (48.81).

With respect to the interactions, the minimum fruit set (29.91) was recorded by Bomby grown under shadow hall ( $S_2H_2$ ) closely followed by Indra grown under shadow hall ( $S_2H_3$ ) (33.14) and Orobelle grown under shadow hall ( $S_2H_1$ ) (35.23).

#### 4.2.3 Number of fruits per plant

The data on number of fruits per plant at different stages of crop growth as influenced by growing structures, hybrids in capsicum and their interactions are presented in Table 6.

The number of fruits per plant of capsicum differed significantly due to growing structures, hybrids and their interactions at all stages of crop growth viz., 60, 90, 120 and 180 days after planting (DAP).

At 60 DAP, among the different structures, number of fruits per plant was maximum (7.11) under polyhouse, which was significantly superior over the other growing structures. The least number of fruits per plant (3.27) was recorded under shadow hall.

Among the hybrids, Indra recorded the maximum (6.54) number of fruits per plant which was significantly superior over the other two hybrids. Indra was followed by Orobelle (5.00) and the least number of fruits was recorded by Bomby (4.70).

With respect to the interactions, the highest number of fruits per plant (8.16) was recorded by Indra grown under polyhouse ( $S_1H_3$ ) closely followed by Orobelle grown under shade house with misting ( $S_3H_1$ ) (7.00).

Among the interactions, the least number of fruits per plant (2.16) was recorded by Bomby grown under shadow hall ( $S_2H_2$ ) closely followed by Orobelle grown under (3.33) shadow hall ( $S_2H_1$ ) and Indra grown under shadow hall ( $S_2H_3$ ) (4.33).

At 120 DAP, among the different structures, number of fruits per plant was maximum (11.66) under polyhouse, which was significantly superior over the other growing structures. The least number of fruits (9.20) was recorded under shadow hall.

Among the three hybrids, Indra recorded the maximum number of fruits per plant (12.11) which was significantly superior over the other two hybrids. Indra was followed by Orobelle (10.00) and the least number of fruits per plant was recorded by Bomby (9.78).

With respect to the interactions, the highest number of fruits per plant (12.33) was recorded by Indra grown under polyhouse ( $S_1H_3$ ) closely followed by Indra grown under shade house without misting ( $S_4H_3$ ) (12.11) and Bomby grown under shade house with misting ( $S_3H_2$ ) (12.00).

**Table 5: Per cent fruit set as influenced by growing structures and hybrids in capsicum**

Treatment	Per cent fruit set
<b>A. Growing structure</b>	
S <sub>1</sub> – Polyhouse	49.81
S <sub>2</sub> – Shadow hall	32.76
S <sub>3</sub> – Shade house with misting	47.03
S <sub>4</sub> – Shade house without misting	43.70
SE m <sub>±</sub>	0.645
CD (P=0.05)	2.231
<b>B. Hybrid</b>	
H <sub>1</sub> – Orabelle (yellow)	42.36
H <sub>2</sub> – Bomby (red)	41.17
H <sub>3</sub> – Indra (green)	45.45
SE m <sub>±</sub>	0.663
CD (P=0.05)	2.603
<b>C. Interaction</b>	
S <sub>1</sub> H <sub>1</sub>	47.81
S <sub>1</sub> H <sub>2</sub>	47.86
S <sub>1</sub> H <sub>3</sub>	52.75
S <sub>2</sub> H <sub>1</sub>	35.23
S <sub>2</sub> H <sub>2</sub>	29.91
S <sub>2</sub> H <sub>3</sub>	33.14
S <sub>3</sub> H <sub>1</sub>	49.81
S <sub>3</sub> H <sub>2</sub>	45.36
S <sub>3</sub> H <sub>3</sub>	47.80
S <sub>4</sub> H <sub>1</sub>	44.02
S <sub>4</sub> H <sub>2</sub>	48.81
S <sub>4</sub> H <sub>3</sub>	41.01
SE m <sub>±</sub>	1.437
CD (P=0.05)	3.312

**Table 6: Number of fruits per plant as influenced by growing structures and hybrids at different stages of crop growth in capsicum**

Treatment	Number of fruits per plant				
	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP
<b>A. Growing structure</b>					
S <sub>1</sub> – Polyhouse	7.11	10.88	11.66	4.50	1.88
S <sub>2</sub> – Shadow hall	3.27	6.05	9.20	3.02	1.33
S <sub>3</sub> – Shade house with misting	6.05	9.44	10.13	4.33	1.61
S <sub>4</sub> – Shade house without misting	5.16	9.11	10.05	3.88	1.55
SE m <sub>±</sub>	0.053	0.102	0.123	0.082	0.091
CD (P=0.05)	0.183	0.352	0.425	0.283	0.314
<b>B. Hybrid</b>					
H <sub>1</sub> – Orabelle (yellow)	5.00	9.83	10.00	4.00	1.62
H <sub>2</sub> – Bomby (red)	4.70	7.29	9.78	3.00	1.37
H <sub>3</sub> – Indra (green)	6.54	10.79	12.11	4.12	2.79
SE m <sub>±</sub>	0.116	0.081	0.117	0.151	0.163
CD (P=0.05)	0.455	0.318	0.459	0.592	0.640
<b>C. Interaction</b>					
S <sub>1</sub> H <sub>1</sub>	6.15	10.00	11.83	4.00	1.33
S <sub>1</sub> H <sub>2</sub>	6.16	9.33	11.00	4.12	1.83
S <sub>1</sub> H <sub>3</sub>	8.16	11.33	12.33	5.00	2.50
S <sub>2</sub> H <sub>1</sub>	3.33	7.50	10.00	2.13	1.32
S <sub>2</sub> H <sub>2</sub>	2.16	5.33	8.00	2.65	1.60
S <sub>2</sub> H <sub>3</sub>	4.33	8.33	10.11	3.50	1.30
S <sub>3</sub> H <sub>1</sub>	7.00	9.50	11.43	4.00	1.50
S <sub>3</sub> H <sub>2</sub>	6.15	7.51	12.00	3.16	1.83
S <sub>3</sub> H <sub>3</sub>	6.10	11.33	11.16	4.50	1.36
S <sub>4</sub> H <sub>1</sub>	5.83	8.33	11.12	3.06	1.32
S <sub>4</sub> H <sub>2</sub>	6.16	7.00	11.21	2.41	2.00
S <sub>4</sub> H <sub>3</sub>	5.32	10.16	12.11	3.50	1.50
SE m <sub>±</sub>	0.347	0.226	0.223	0.320	0.315
CD (P=0.05)	1.069	0.696	0.687	0.986	0.970

DAP – Days after planting



Orobelle



Bomby



Indra

Plate 3: General view of fruits under protected structures

Among the interactions, the least number of fruits per plant (8.00) was recorded by Bomby grown under shadow hall ( $S_2H_2$ ) closely followed by Orobelle grown under shadow hall ( $S_2H_1$ ) (10.00) which was on par with Indra grown under shadow hall ( $S_2H_3$ ) (10.11).

### 4.3 Quality parameters

The data on fruit weight (g) and fruit volume (cc) as influenced by growing structures, hybrids in capsicum and their interactions are presented in Table 7.

#### 4.3.1 Fruit weight and volume

##### 4.3.1.1 Fruit weight (g)

Among the different structures, the average fruit weight was higher (160.00 g/fruit) under polyhouse which was significantly superior over the other growing structures. The lowest fruit weight (135.80 g fruit) was recorded under shadow hall.

Among the three hybrids, Bomby recorded highest fruit weight (158.50 g/fruit) which was significantly superior over the other two hybrids. Bomby was followed by Orobelle (150.00 g/fruit) and Indra (147.50g/fruit).

With respect to the interactions, the highest fruit weight (173.00 g/fruit) was recorded by Bomby grown under polyhouse ( $S_1H_2$ ) closely followed by Orobelle grown under (172.10 g/fruit) polyhouse ( $S_1H_1$ ) and Bomby grown under shade house with misting ( $S_1H_3$ ) (170.00 g/fruit).

With respect to the interactions, the minimum fruit weight (130.62) was recorded by Indra grown under shadow hall ( $S_2H_3$ ) closely followed by Bomby grown under shade house without misting ( $S_4H_2$ ) (132.11 g/fruit) and Orobelle grown under shade house with misting ( $S_3H_1$ ) (145.61 g/fruit).

##### 4.3.1.2 Fruit volume (cc/fruit)

Among the different structures, the average fruit volume was higher (320.00 cc/fruit) under polyhouse which was significantly superior over the other growing structures. The lower fruit volume (241.00 cc/fruit) was recorded under shadow hall.

Among the three hybrids, Bomby recorded higher fruit volume (310.00 cc/fruit) which was significantly superior over the other two hybrids. Bomby was followed by Orobelle (300.00 cc/fruit) and Indra (289.00 cc/fruit).

With respect to the interactions, the highest fruit volume (346.00 cc/fruit) was recorded by Bomby grown under polyhouse ( $S_1H_2$ ) closely followed by Orobelle grown under polyhouse ( $S_1H_1$ ) (344.20 cc/fruit) and Indra grown under polyhouse ( $S_1H_3$ ) (334.00 cc/fruit).

With respect to the interactions, the minimum fruit volume (240.46 cc/fruit) was recorded by Bomby grown under shade house with misting ( $S_3H_2$ ) closely followed by Indra grown under (260.24 cc/fruit) shade house with misting ( $S_2H_3$ ) and Orobelle grown under (260.46 cc/fruit) shade house without misting ( $S_4H_1$ ).

#### 4.3.2 Rind thickness (cm) and Shelf life (days)

The data on rind thickness (cm) and shelf life (days) as influenced by growing structures, hybrids in capsicum and their interactions are presented in Table 8.

##### 4.3.2.1 Rind thickness (cm)

Pericarp thickness elicited moderate variation under different growing structures. Among the different structures, the higher rind thickness (0.91 cm) was recorded under polyhouse which was on par with shade house with misting and shade house without misting. The lower rind thickness (0.74 cm) was recorded under shadow hall.

**Table 7: Fruit weight (g) and fruit volume (cc) as influenced by growing structures and hybrids in capsicum**

Treatment	Fruit weight (g)	Fruit volume (cc)
<b>A. Growing structure</b>		
S <sub>1</sub> – Polyhouse	160.00	320.00
S <sub>2</sub> – Shadow hall	135.80	241.00
S <sub>3</sub> – Shade house with misting	152.00	295.00
S <sub>4</sub> – Shade house without misting	148.50	287.50
SE m <sub>±</sub>	0.196	0.636
CD (P=0.05)	0.678	2.200
<b>B. Hybrid</b>		
H <sub>1</sub> – Orobelle (yellow)	150.00	300.00
H <sub>2</sub> – Bomby (red)	158.50	310.00
H <sub>3</sub> – Indra (green)	147.50	289.00
SE m <sub>±</sub>	0.146	0.524
CD (P=0.05)	0.573	2.057
<b>C. Interaction</b>		
S <sub>1</sub> H <sub>1</sub>	172.10	344.20
S <sub>1</sub> H <sub>2</sub>	173.00	346.00
S <sub>1</sub> H <sub>3</sub>	170.00	334.00
S <sub>2</sub> H <sub>1</sub>	167.00	324.00
S <sub>2</sub> H <sub>2</sub>	165.23	284.00
S <sub>2</sub> H <sub>3</sub>	130.62	260.24
S <sub>3</sub> H <sub>1</sub>	145.61	290.22
S <sub>3</sub> H <sub>2</sub>	170.23	240.46
S <sub>3</sub> H <sub>3</sub>	155.11	288.52
S <sub>4</sub> H <sub>1</sub>	149.36	260.46
S <sub>4</sub> H <sub>2</sub>	132.11	264.22
S <sub>4</sub> H <sub>3</sub>	158.50	276.10
SE m <sub>±</sub>	1.373	1.418
CD (P=0.05)	4.229	4.367

**Table 8: Rind thickness (cm) and shelf life (days) as influenced by growing structures and hybrids in capsicum**

Treatment	Rind thickness (cm)	Shelf life (days)
<b>A. Growing structure</b>		
S <sub>1</sub> – Polyhouse	0.91	8.62
S <sub>2</sub> – Shadow hall	0.74	8.00
S <sub>3</sub> – Shade house with misting	0.85	8.30
S <sub>4</sub> – Shade house without misting	0.80	8.07
SE m <sub>±</sub>	0.045	0.084
CD (P=0.05)	0.179	0.290
<b>B. Hybrid</b>		
H <sub>1</sub> – Orabelle (yellow)	0.72	7.97
H <sub>2</sub> – Bomby (red)	0.84	8.17
H <sub>3</sub> – Indra (green)	0.87	8.60
SE m <sub>±</sub>	0.382	0.077
CD (P=0.05)	NS	0.302
<b>C. Interaction</b>		
S <sub>1</sub> H <sub>1</sub>	0.88	8.36
S <sub>1</sub> H <sub>2</sub>	0.91	8.50
S <sub>1</sub> H <sub>3</sub>	0.95	9.01
S <sub>2</sub> H <sub>1</sub>	0.74	7.63
S <sub>2</sub> H <sub>2</sub>	0.73	7.70
S <sub>2</sub> H <sub>3</sub>	0.82	7.83
S <sub>3</sub> H <sub>1</sub>	0.51	8.08
S <sub>3</sub> H <sub>2</sub>	0.87	8.40
S <sub>3</sub> H <sub>3</sub>	0.90	8.41
S <sub>4</sub> H <sub>1</sub>	0.83	8.68
S <sub>4</sub> H <sub>2</sub>	0.85	8.08
S <sub>4</sub> H <sub>3</sub>	0.86	8.32
SE m <sub>±</sub>	0.773	0.11
CD (P=0.05)	NS	0.342

NS – Non-significant

There was non significant difference among the hybrids with respect to pericarp thickness. Also, among the interactions, there was non significant difference with respect to pericarp thickness.

#### 4.3.2.2 Shelf life (days)

Among the different structures, the fruits grown under polyhouse recorded higher shelf life (8.62 days) which was significantly superior over the other growing structures. The lower shelf life (8.00 days) was recorded under shadow hall.

Among the three hybrids, Indra recorded higher shelf life (8.60 days) which was significantly superior over the other two hybrids. Indra was followed Bomby (8.17 days) and Orobelle (7.97days).

With respect to the interactions, the higher shelf life (9.01 days) was recorded by Indra grown under polyhouse ( $S_1H_3$ ) closely followed by Orobelle grown under shade house without misting ( $S_4H_1$ ) (8.68 days) and Bomby grown under polyhouse ( $S_1H_2$ ) (8.50 days).

With respect to the interactions, the lower shelf life (7.63 days) was recorded by Orobelle grown under shadow hall ( $S_2H_1$ ) closely followed by Bomby grown under shadow hall ( $S_2H_2$ ) (7.70 days) and Indra grown under shadow hall ( $S_2H_3$ ) (7.83 days).

## 4.4 Yield parameters

The data on yield per plant (kg) and yield per hectare (ton) as influenced by growing structures, hybrids in capsicum and their interactions are presented in Table 9.

### 4.4.1 Yield per plant (kg)

Among the different structures, the higher yield (3.26 kg/plant) was recorded under polyhouse which was significantly superior over the other growing structures. The lowest yield (1.66 kg/plant) was recorded under shadow hall.

Among the three hybrids, Indra recorded higher yield (2.63 kg/plant) which was significantly superior over the other two hybrids. Indra was followed by Orobelle (2.38 kg/plant) and Bomby (2.19 kg/plant).

With respect to the interactions, the highest fruit yield (3.43 kg/plant) was recorded by Indra grown under polyhouse ( $S_1H_3$ ) closely followed by Orobelle grown under polyhouse ( $S_1H_1$ ) (3.26 kg/plant) and Bomby grown under polyhouse ( $S_1H_2$ ) (3.10 kg/plant).

With respect to the interactions, the minimum fruit yield (1.40 kg/plant) was recorded by Bomby grown under shadow hall ( $S_2H_2$ ) closely followed by Orobelle grown under shadow hall ( $S_2H_1$ ) (1.71 kg/plant) and Orobelle grown under polyhouse ( $S_4H_1$ ) (1.83 kg/plant).

### 4.4.2 Yield per hectare (ton)

Among the different structures, the highest yield (72.52 t/ha) was recorded under polyhouse which was significantly superior over the other growing structures. The lower yield (36.92 t/ha) was recorded under shadow hall.

Among the three hybrids, Indra recorded higher yield (58.49 t/ha) which was significantly superior over the other two hybrids. Indra was followed by Orobelle (53.22 t/ha) and Bomby (49.55 t/ha).

With respect to the interactions, the highest fruit yield (76.22 t/ha) was recorded by Indra grown under polyhouse ( $S_1H_3$ ) closely followed by Orobelle grown under polyhouse ( $S_1H_1$ ) (72.52 t/ha) and Bomby grown under polyhouse ( $S_1H_2$ ). (68.82 t/ha).

With respect to the interactions, the minimum fruit yield (31.08 t/ha) was recorded by Bomby grown under shadow hall ( $S_2H_2$ ) closely followed by Orobelle grown under shadow hall ( $S_2H_1$ ) (36.26 t/ha) and Indra grown under shadow hall ( $S_2H_3$ ) (38.10 t/ha).

**Table 9: Yield per plant (kg) and yield per hectare (t) as influenced by growing structures and hybrids in capsicum**

Treatment	Yield per plant (kg)	Yield per hectare (t)
<b>A. Growing structure</b>		
S <sub>1</sub> – Polyhouse	3.26	72.52
S <sub>2</sub> – Shadow hall	1.66	36.92
S <sub>3</sub> – Shade house with misting	2.62	60.18
S <sub>4</sub> – Shade house without misting	2.06	45.92
SE m <sub>±</sub>	0.086	1.496
CD (P=0.05)	0.297	5.176
<b>B. Hybrid</b>		
H <sub>1</sub> – Orabelle (yellow)	2.38	53.22
H <sub>2</sub> – Bomby (red)	2.19	49.55
H <sub>3</sub> – Indra (green)	2.63	58.49
SE m <sub>±</sub>	0.032	0.435
CD (P=0.05)	0.125	1.707
<b>C. Interaction</b>		
S <sub>1</sub> H <sub>1</sub>	3.26	72.52
S <sub>1</sub> H <sub>2</sub>	3.10	68.82
S <sub>1</sub> H <sub>3</sub>	3.43	76.22
S <sub>2</sub> H <sub>1</sub>	1.71	36.26
S <sub>2</sub> H <sub>2</sub>	1.40	31.08
S <sub>2</sub> H <sub>3</sub>	1.87	38.10
S <sub>3</sub> H <sub>1</sub>	2.65	63.64
S <sub>3</sub> H <sub>2</sub>	2.43	54.76
S <sub>3</sub> H <sub>3</sub>	2.80	62.16
S <sub>4</sub> H <sub>1</sub>	1.83	41.58
S <sub>4</sub> H <sub>2</sub>	2.14	47.50
S <sub>4</sub> H <sub>3</sub>	2.43	54.02
SE m <sub>±</sub>	0.115	1.809
CD (P=0.05)	0.354	5.574

**Table 10: Monthly mean, weather data recorded during the experimental period from February, 2007 to August 2007**

Month	Temperature (°C)								Relative humidity (%)								Light intensity (K-lux)				Rainfall (mm)
	S <sub>1</sub>		S <sub>2</sub>		S <sub>3</sub>		S <sub>4</sub>		S <sub>1</sub>		S <sub>2</sub>		S <sub>3</sub>		S <sub>4</sub>		S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.					
February	34.50	20.13	33.01	18.99	32.90	18.34	33.12	19.60	80.93	32.43	82.17	33.12	50.00	20.42	40.13	22.12	33.91	24.00	31.28	31.00	0.00
March	38.80	21.07	36.10	19.11	37.20	20.00	36.17	19.79	75.20	28.24	78.99	30.00	55.16	21.80	42.16	23.00	35.24	32.46	32.46	33.15	0.42
April	39.40	23.85	36.03	21.00	37.12	22.11	36.10	21.19	81.75	28.63	82.11	30.11	60.10	20.24	49.00	29.16	41.32	31.21	38.16	39.41	2.97
May	36.85	23.08	21.52	33.11	22.88	34.41	21.86	34.15	82.50	41.00	83.67	43.00	63.79	25.34	51.61	30.00	34.49	29.64	31.43	33.23	1.43
June	31.25	23.41	21.17	28.51	22.12	29.78	21.13	29.65	91.20	69.48	91.83	70.00	65.85	28.31	55.11	31.11	30.07	26.11	27.87	26.19	8.46
July	28.79	23.80	21.11	25.69	22.08	26.98	21.10	26.73	90.00	82.37	90.80	79.12	61.40	29.00	54.13	32.00	28.39	24.51	26.94	25.66	8.33
August	29.53	22.35	22.35	26.19	20.93	20.86	20.00	27.00	93.71	79.24	91.00	76.23	62.02	27.10	50.13	30.99	26.19	23.23	24.38	23.17	7.65

S<sub>1</sub> – Naturally ventilated Polyhouse  
 S<sub>2</sub> – Naturally ventilated Shadow hall  
 S<sub>3</sub> – Shade house with misting  
 S<sub>4</sub> – Shade house without misting

## 4.5 Environmental parameters

### 4.5.1 Temperature (°C), Relative humidity (%), Light intensity (Klux) and Rainfall (mm)

The data pertaining to temperature (°C), relative humidity (%), light intensity (klux) and rainfall (mm), recorded during the period of study are presented in Table 10.

#### 4.5.1.1 Temperature (°C)

The maximum temperature (39.40°C) was recorded under naturally ventilated polyhouse in the month of April and minimum temperature (18.34°C) was recorded under shade house with misting in the month of February.

#### 4.5.1.2 Relative humidity (%)

The maximum relative humidity (93.71%) was recorded under poly house in the month of August and minimum relative humidity (20.24%) was recorded under shade house with misting in the month of April.

#### 4.5.1.3 Light intensity (klux)

The maximum light intensity (41.32 klux) was recorded under naturally ventilated polyhouse in the month of April and minimum light intensity (23.17 klux) was recorded under shade house without misting in the month of August.

#### 4.5.1.4 Rainfall (mm)

The maximum rainfall (8.46 mm) was recorded in the month of June and no rainfall (0 mm) was recorded in the month of February.

## 4.6 Economics

### 4.6.1 Cost of cultivation of capsicum hybrids under different protected structures (500 m<sup>2</sup>) for one year presented in Table 11.

#### 4.6.1.1 Cost of infrastructure facility

The maximum total appositional cost (Rs.60241.41) was recorded in naturally ventilated polyhouse and the minimum cost (Rs.25409.58) was recorded under shade house without misting.

#### 4.6.1.2 Total cost of cultivation of capsicum hybrids under different protected structures (500 m<sup>2</sup>) for one year presented in Table 12.

The higher fruit yield (7614.60 kg/500m<sup>2</sup>/year) was recorded under naturally ventilated polyhouse and lower fruit yield (3108 kg/500m<sup>2</sup>/year) was recorded under shadow hall.

The higher gross income (Rs. 304584) and net income (Rs. 214089.83) was recorded under naturally ventilated polyhouse. While, lower the gross income (Rs.87024) and net income (Rs. 4205.42) was recorded under shadow hall.

With respect to benefit cost ratio, shade house with misting (2.70) was found to be superior over the others. T<sub>5</sub> recorded the lower (1.17) benefit cost ratio.

**Table 11: Calculation of detailed cost of cultivation of capsicum hybrids (Orobelle, Bomby and Indra) under different protected structures (500 m<sup>2</sup>) for one year**

**1. Cost of infrastructure facilities**

Sl. No.	Particular	Total cost (Rs.)	Depreciated cost (Rs.) for one year
<b>A</b>	<b>Naturally ventilated polyhouse</b>		
1	Structure/drip irrigation facilities		
a)	Structure (excluding cladding material) Rs. 350/m <sup>2</sup> for life span of 15 years	192857	12857.13
b)	Cladding material @ Rs. 45/m <sup>2</sup> for 3000 m <sup>2</sup> for life span of 4 years	135000	33750.00
c)	Drip irrigation system @ Rs. 55/m <sup>2</sup> for life span of 10 years	27500	2750.00
2	Interest on fixed cost (a, b and c) @ 18% per annum		8884.28
3	Repair and maintenance cost		2000.00
	Total apparitional cost		60241.41
<b>B</b>	<b>Naturally ventilated shadow hall</b>		
1	Structure/drip irrigation facilities		
a)	Structure (excluding cladding material) Rs. 350/m <sup>2</sup> for life span of 15 years	2,00,000	13,3333.00
b)	Cladding material i) shade net 2500/m <sup>m</sup> @ Rs. 25/m <sup>2</sup> for life span of 4 years	62,500	15625.00
	ii) film 1000/m <sup>2</sup> @ 40/m <sup>2</sup> for life span of 4 years	40,000	10,000.00
c)	Drip irrigation system @ Rs. 55/m <sup>2</sup> for life span of 10 years	27,500	2,750.00
2	Interest on fixed cost (a, b and c) @ 18% per annum		7507.4994
3	Repair and maintenance cost		2500.00
	Total apparitional cost		51715.829
<b>C</b>	<b>Shade house with misting</b>		
1	Structure/drip irrigation facilities		
a)	Structure (excluding cladding material) Rs. 350/m <sup>2</sup> for life span of 15 years	75000	7500.00

*Contd...*

b)	Cladding material @ Rs. 45/m <sup>2</sup> for 3000 m <sup>2</sup> for life span of 4 years	27500	10266.60
c)	i) Drip irrigation system @ Rs. 55/m <sup>2</sup> for life span of 10 years	27500	2750.00
	ii) Misting facility @ 15/m <sup>2</sup> for life span of 10 years	7500	750.00
2	Interest on fixed cost (a, b and c) @ 18% per annum		3827.98
3	Repair and maintenance cost		1500.00
	Total apparitional cost		26594.58
<b>D</b>	<b>Shade house without misting</b>		
1	Structure/drip irrigation facilities		
a)	Structure (excluding cladding material) Rs. 350/m <sup>2</sup> for life span of 15 years	75000	7500.00
b)	Cladding material @ Rs. 45/m <sup>2</sup> for 3000 m <sup>2</sup> for life span of 4 years	27500	10266.60
c)	Drip irrigation system @ Rs. 55/m <sup>2</sup> for life span of 10 years	27500	2750.00
2	Interest on fixed cost (a, b and c) @ 18% per annum		3692.988
3	Repair and maintenance cost		1200.00
	Total apparitional cost		25409.58

## II. Cost of planting material

Spacing	Planting density	Polyhouse (Rs.)	Shadow hall (Rs.)	Shade house with misting (Rs.)	Shade house without misting (Rs.)
45 x 60 cm	1110 seedlings/500 m <sup>2</sup>	1665	1665	1665	1665

## III. Cost of growing media and its preparation

Sl. NO.	Particular	Polyhouse (Rs.)	Shadow hall (Rs.)	Shade house with misting (Rs.)	Shade house without misting (Rs.)
1	Media (Sand + red soil + FYM + neem cake + vermicompost)	5000	5000	5000	5000
2	Fumigation (with 2% formaldehyde) 40 m <sup>3</sup> /m <sup>2</sup> for 500 m <sup>2</sup> = 20 lit @ Rs. 47/lit	940	940	940	940
3	Labour cost (15 man days @ Rs. 80/day)	1200	1200	1200	1200
	Total	7140	7140	7140	7140

## IV. Cost of fertigation

19:19:19		12:61:0		0:0:50		13:10:26		Total (Rs.)
Quantity (kg)	Cost (Rs.)	Quantity (kg)	Cost (Rs.)	Quantity (kg)	Cost (Rs.)	Quantity (kg)	Cost (Rs.)	
21.01	945.45	21.01	903.43	21.01	903.43	21.01	945.45	3697.76
19:19:19- Rs. 45/kg		12:61:0- Rs. 43/kg		0:0:50- Rs. 43/kg		13:10:26- Rs. 45/kg		

#### V. Cost of micronutrient and mulching

Micronutrient cost	Polyhouse (Rs.)	Shadow hall (Rs.)	Shade house with misting (Rs.)	Shade house without misting (Rs.)
Mulching	400	400	400	400
Cost	800	800	800	800
<b>Total</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>	<b>1200</b>

#### VI. Cost of plant protection chemicals

Sl. No.	Plant protection chemical	Polyhouse (Rs.)	Shadow hall (Rs.)	Shade house with misting (Rs.)	Shade house without misting (Rs.)
1	Insecticides spray	1250	1500	2000	2500
2	Fungicides spray	1300	1900	2500	2900
	<b>Total</b>	<b>2550</b>	<b>3400</b>	<b>4500</b>	<b>5400</b>

#### VII. Cost of labour

Sl. No.	Labour	Polyhouse (Rs.)	Shadow hall (Rs.)	Shade house with misting (Rs.)	Shade house without misting (Rs.)
1	Men-100 man days @ Rs. 80/day	8000	8000	8000	8000
2	Women-100 man days @ Rs. 60/day	6000	6000	6000	6000
	<b>Total</b>	<b>14000</b>	<b>14000</b>	<b>14000</b>	<b>14000</b>

**Table 12 : Total cost of cultivation of capsicum hybrids (Orabelle Bomby and Indra) grown under different protected structures (500 m<sup>2</sup>) for one year**

Treatment	Fruit yield (kg/500 m <sup>2</sup> /year)	Cost of cultivation/ 500 m <sup>2</sup> (Rs.)	Gross income (Rs.)	Net income (Rs.)	B:C ratio
T <sub>1</sub> (S <sub>1</sub> H <sub>1</sub> )	6882.00	90494.17	275280	184785.83	2.04
T <sub>2</sub> (S <sub>1</sub> H <sub>2</sub> )	7237.20	90494.17	289488	198993.83	2.19
T <sub>3</sub> (S <sub>1</sub> H <sub>3</sub> )	7614.60	90494.17	304584	214089.83	2.36
T <sub>4</sub> (S <sub>2</sub> H <sub>1</sub> )	3796.20	82181.58	106293	23475.42	1.28
T <sub>5</sub> (S <sub>2</sub> H <sub>2</sub> )	3108.00	82181.58	87024	4205.42	1.17
T <sub>6</sub> (S <sub>2</sub> H <sub>3</sub> )	4151.40	82181.58	116239	33420.42	1.43
T <sub>7</sub> (S <sub>3</sub> H <sub>1</sub> )	5883.00	58797.34	205905	147107.66	2.50
T <sub>8</sub> (S <sub>3</sub> H <sub>2</sub> )	5394.60	58797.34	188811	130013.66	2.21
T <sub>9</sub> (S <sub>3</sub> H <sub>3</sub> )	6216.00	58797.34	217560	158762.66	2.70
T <sub>10</sub> (S <sub>4</sub> H <sub>1</sub> )	4062.60	58512.34	130003	71490.86	1.22
T <sub>11</sub> (S <sub>4</sub> H <sub>2</sub> )	4750.80	5812.34	152025	93513.86	1.59
T <sub>12</sub> (S <sub>4</sub> H <sub>3</sub> )	5394.60	5812.34	172627	114114.86	1.95

## 5. DISCUSSION

Growth, development, productivity and post-harvest quality of any crop largely depend upon the interaction between the genetic constitution of the plants and the environmental conditions under which they are grown. Every plant species has its own specific inherent characters such as colour, size, growth rate, storability, cooking and processing qualities. The atmospheric condition under which it is grown has a large bearing on the realization of its genetic potential. Capsicum is one such crop, which responds very well to the favourable environmental conditions. Under modern vegetable production technology, a great emphasis is given to have appropriate plant density and proper training level in order to boost up the production per unit area.

In the present investigation, four structures were adopted namely, naturally ventilated poly house, shadow hall, shade house with misting and shade house without misting as well as three hybrids like Orobelle (yellow), Bomby (red) and Indra (green) to know the performance of capsicum hybrids under different protected structures. The results obtained are discussed here under.

### 5.1 Vegetative parameters as influenced by different growing structures, hybrids in capsicum

During the successive stages of crop growth *viz.*, 30, 60, 90 and 120 days after planting (DAP), the plant height of capsicum was found to be increasing and it was 155.73 cm at 120 DAP under naturally ventilated polyhouse followed by shadow hall (136.38 cm). 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 as compared to shadow hall. The results of higher growth rate under polyhouse structure were reported by Maurer (1981) in bell pepper and More *et al.* (1990) in cucumber.

Among the hybrids the highest plant height (157.75 cm) was recorded in Orobelle followed by Bomby (132.62 cm) at 120 DAP. With regard to interaction effect, the naturally ventilated polyhouse x Orobelle ( $S_1 \times H_1$ ) recorded higher (145.00 cm) plant height at 120 DAP. The least (41.16 cm) plant height was recorded under shade house without misting x Bomby ( $S_4 \times H_3$ ) at 30 DAP.

The number of leaves per plant were maximum (110.27) under polyhouse at 120 DAP. This might be due to the taller plants, increased number of branches and the congenial microclimate that prevailed inside the polyhouse favouring increased growth rate of plants, similar results were obtained by Ochigbu *et al.* (1989) in cucumber.

Among the hybrids, the maximum (103.83) number of leaves per plant were noticed in Orobelle at 120 DAP. This may be attributed to stout plants produced by the hybrid, exploiting the available space, nutrients and light resources favouring fast vegetative growth.

The interaction effect of polyhouse x Orobelle ( $S_1 \times H_1$ ) showed maximum (125.00) number of leaves per plant at 120 DAP. This is also in support of the individual effects of polyhouse and Orobelle hybrid.

The least number of days taken for flower initiation (33.00 days) was recorded under polyhouse structure. This may be due to accumulation of maximum photosynthates favouring fast growth which triggered early initiation of flowers under polyhouse. Similar results were obtained by Rui *et al.* (1989) in capsicum.

Similarly, plants grown under polyhouse recorded early (86.00 days) harvesting as compare to shadow hall (87.22 days), which might be due to high temperature that prevailed inside polyhouse, that acted as a stress and allowed plants to complete there life cycle at faster rate. The interaction effect of ( $S_1 \times H_3$ ) polyhouse x Indra recorded early (85.23 days) harvesting, among the different interactions.

Among the hybrids, Indra recorded the least (35.42 days) number of days for flower initiation and first harvest (86.00 days), which might be due to its greater capacity for accumulation of more photosynthates that favoured induction of early flowering compared to Orobelle.

The interaction combination of polyhouse x Indra ( $S_1 \times H_3$ ) recorded the least time taken for flower initiation (36.66 days) while the combination of Indra x shadow hall ( $S_2H_3$ ) recorded the least number of days to first harvest (81.33 days)

## 5.2 Reproductive parameters as influenced by different growing structures, hybrids in capsicum

Plants grown under polyhouse recorded more (12.44) numbers of flowers per plant followed by shade house with misting (11.55) at 120 DAP. This could be attributed to the increased number of secondary branches per plant that were produced under polyhouse structure. The hybrid Indra recorded maximum (13.41) numbers of flowers per plant at 120 DAP.

The interaction effect of polyhouse x Indra ( $S_1 \times H_3$ ) were recorded the maximum (14.66) number of flowers per plant at 120 DAP, which might be due to favourable climatic condition coupled with faster growth, higher number of secondary branches, sufficient accumulation of photosynthates and less of flower dropping inside the polyhouse as compared to shadow hall. Similar findings were recorded by Bhatt and Rao (1993).

The highest per cent fruit set (49.81%) was recorded under polyhouse followed by shade house with misting (47.03%). This was a consequence of production of more flowers per plant and less interference of adverse climatic conditions like rainfall and wind velocity during crop growth and development. Among hybrids, Indra recorded the highest (45.45%) percent fruit set.

Also the interaction effect of polyhouse x Indra ( $S_1 \times H_3$ ) recorded the highest per cent of fruit set (52.75%). This might be due to good vegetative growth besides effective pollination and fertilization and lower abscission rate of flowers. Similar results were recorded by Backer (1989) in sweet pepper.

The number of fruits per plant was higher (11.66) at 120 DAP, under naturally ventilated polyhouse than shadow hall (9.20). This might be due to the more number of flowers and maximum per cent fruit set under naturally ventilated polyhouse. The hybrid Indra recorded maximum numbers of fruits (12.11) at 120 DAP due to more number of flowers and a high value of per cent fruit set because of vigorous and healthy plants. With regard to interaction effects the naturally ventilated polyhouse x Indra ( $S_1 \times H_3$ ) recorded maximum (12.33) fruits at 120 DAP. This might be due to congenial climate. Similar observations were recorded by Backer (1989) in sweet pepper.

## 5.3 Quality parameters as influenced by different growing structures, hybrids in capsicum

The fruit weight and volume play an important role in increasing the total yield in capsicum. The weight and volume of the fruits grown under naturally ventilated polyhouse were higher (160.00 g and 320.00 cc) as compared to shadow hall structure. This was largely due to the increased length and breadth of fruit. The hybrid Bomby recorded higher (158.5 g and 310.00 cc) fruit weight and volume. This could be due to a high uptake of nutrients and build up of sufficient photosynthates enabling the increase in size of fruits (length and breadth), resulting in the increased fruit weight and volume in that hybrid. Similar findings were recorded by Buitelaar and Janse (1987) in tomato and Mohomedien (1991) in cucumber.

Among the interaction effects, the higher (173.00 g and 346.00 cc) weight and volume were recorded under naturally ventilated polyhouse x Bomby hybrid ( $S_1 \times H_2$ ).

The higher rind thickness (0.91 cm) was recorded under naturally ventilated polyhouse than shadow hall (0.74 cm). There was non significant difference among hybrids and interaction between growing conditions and hybrids with respect to rind thickness. However, it was found to be higher in Indra (0.87 cm) and in polyhouse x Indra interaction (0.95 cm).

The shelf life of capsicum hybrids is an important quality parameter because it directly influences the time that can be taken before marketing the produce.

Fruits grown under naturally ventilated polyhouse recorded significantly higher (8.62 days) shelf life followed by shade house with misting (8.30 days). The hybrid Indra recorded a higher (8.60 days) shelf life. This is because of the fruits having thicker pericarp. Among the interaction effect the polyhouse x Indra hybrid ( $S_1 \times H_3$ ) recorded a higher (9.01 days) shelf life. Similar results were recorded by Rai (1995) in capsicum.

#### 5.4 Yield parameters as influenced by different growing structures, hybrids in capsicum

The marketable fruit yield of capsicum was higher (3.26 kg/plant and 72.52 t/ha) under naturally ventilated polyhouse as compared to shadow hall (1.66 kg/plant and 36.92 t/ha). This may be attributed to the favourable climatic conditions that prevailed under naturally ventilated polyhouse, leading to higher vegetative growth, contributing to more number of flowers, more number of fruits, higher per cent of fruit set, maximum fruit weight and fruit volume. Similar results were obtained by Nagendra prasad (2001).

Among the hybrids, Indra recorded higher (2.63 kg/plant and 58.49 t/ha) fruit yield as compare to Bomby hybrid (2.19 kg/plant and 49.95 t/ha). This might be due to the higher number of flowers, fruits and maximum extent of fruit set. With regard to interaction effect, the polyhouse x Indra hybrid ( $S_1 \times H_3$ ) recorded higher fruit yield (3.43 kg/plant and 76.52 t/h). Similar results were obtained by Grangs and Leger (1989) in capsicum.

#### 5.5 Effect of environmental parameters on growth and development of plants

Environment is the aggregate of all external conditions which influences the growth and development of crop, that which play dominant role in crop production. Each crop has its own set of environmental conditions under which it grows best. 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.

Among the environmental factors, the temperature, relative humidity, light intensity and rainfall are the factors which mainly influence the crop growth and development considerably. Solar radiation consists of different wave lengths of light, in which only the visible portion is useful for crop growth, while ultraviolet and infrared radiations are not beneficial for the crop growth, as they bring changes at molecular level that leads to cellular disorganization of the crops grown under open environment. However, excellent growth and higher yield is generally realized in the crops grown under greenhouse, because the covering structure has the property of absorbing UV and infrared radiations.

Temperature is the major regulator of the development process. It influences the flower and fruit development. Temperature was higher in the month of April under polyhouse. The effect of temperature on net photosynthesis is of vital concern in crop production. The higher temperatures have more adverse influence on net photosynthesis than lower temperature leading to decreased production of photosynthates above a certain temperature (Bhatt and Rao 1989). The temperature can be controlled and regulated under protected structure, therefore healthy and better growth of plants can be expected under protected structures.

Atmospheric moisture also plays a significant role in crop growth and development. The maximum relative humidity was recorded in the month of August under polyhouse. The 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.

The light intensity was maximum in the month of April under naturally ventilated polyhouse and maximum rainfall was recorded in month of June.

## 5.6 Incidence of pest and diseases

It was observed that incidence of pests and diseases was comparatively lower (5 and 10%, respectively) under naturally ventilated polyhouse as compared to shade house with misting (15 and 25%, respectively). In summer months, there was less incidence of pests and diseases. When rains started, the incidence of pest and diseases was more under shade house with misting, because in shade house structure, rain water entered easily and there was loss of yield and quality of fruits. Increase in relative humidity (91%) in rainy days resulted in favourable condition for diseases like die back, fruit rot, sclerotium rot and powdery mildew and therefore caused heavy loss and resulted in less yield with lower quality of capsicum fruits under shade house structure. It was noted that the pests like thrips, mites and fruit borer were also more under shade house with misting than under naturally ventilated polyhouse.

## 5.7 Economics and practical utility

Growing capsicum under polyhouse was not only productive (7614.60 kg/500m<sup>2</sup>/year) compared to shadow hall structure (3108.00 kg/500m<sup>2</sup>/year) but also profitable in obtaining fruits of excellent quality fetching relatively higher price.

Gross income was higher (Rs.304584) under naturally ventilated polyhouse structure which was mainly due to higher fruit yield obtained in this structure.

Higher (Rs. 214089.83) net income was obtained by treatment polyhouse x Indra because of a higher gross income by this treatment as a consequence of higher fruit yield.

Among the different protected structures, the shade house with misting was found better with respect to benefit cost ratio. In naturally ventilated polyhouse, the cost of cultivation per year per 500m<sup>2</sup> was found to be more than shade house with misting structure by 2.34 per cent.

Based on the results obtained from the present investigation the following practices for cultivation of capsicum under protected structures may be recommended under transitional tract of Northern Karnataka.

1. Higher yield and quality of fruits in capsicum can be obtained by Indra hybrid as compared to others.
2. Higher individual fruit weight and volume can be obtained by Bomby hybrid as compared to others.
3. Higher yield and quality of capsicum can be obtained under naturally ventilated polyhouse compare to shadow hall structure.
4. The benefit cost ratio was maximum under shade house with misting structure.

#### Future line of work

1. Effect of shade nets with different percentages of shade on growth and development of capsicum need to be studied.
2. Performance of different hybrids should be evaluated under different growing structures.
3. Performance of different vegetables suiting to local and export quality during different seasons under polyhouse need to be studied.
4. Detailed study of different organics and inorganics and their combination on growth and yield of capsicum under protected structures need to be taken up.
5. Interaction of nutrients along with growth regulators need to be studied for enhancing the quality of capsicum or other vegetables under different environmental conditions.
6. Standardization of optimum level of environmental factors (relative humidity, temperature, light intensity, etc.) for higher yields under transitional tract of Northern Karnataka needs to be performed.
7. Study on the physiological processes/changes in response to altered environment on crop growth and productivity of commercial vegetables is to be taken up.

## 6. SUMMARY AND CONCLUSIONS

An experiment was conducted at Main Agricultural Research Station, Saidapur Farm, University of Agricultural Sciences, Dharwad, during February to August, 2007 to study the performance of capsicum hybrids under different protected structures. The treatments comprised of four growing environments viz., naturally ventilated polyhouse, shadow hall, shade house with misting and shade house without misting and three hybrids namely, Orobelle, Bomby and Indra. The experiment was laid out in strip plot design with three replications. The salient findings of the study are summarized below.

1. In case of vegetative characters, the maximum plant height was recorded under naturally ventilated polyhouse than shadow hall structure at all growth stages. Among the hybrids, the higher plant height was recorded in Orobelle at all stages of crop growth. Among the interactions, Orobelle under polyhouse ( $S_1 \times H_1$ ) exhibited significantly higher plant height at 120 DAP.
2. The higher numbers of leaves per plant were observed under polyhouse structure than shade house without misting. The hybrid Orobelle recorded maximum number of leaves per plant. The interaction combination of Orobelle under polyhouse ( $S_1 \times H_1$ ) recorded maximum number of leaves at 120 DAP.
3. Days taken for flower initiation were significantly lower in polyhouse followed by shade house with misting. Among the hybrids, the early flower initiation were noticed in Indra than Orobelle hybrid. The interaction combination of Indra under polyhouse ( $S_1 \times H_3$ ) recorded the earliest flower initiation.
4. Time taken for harvest was the least under naturally ventilated polyhouse which was on par with shade house with misting. Among the hybrids, Indra recorded the least time taken for first harvest.
5. Number of flowers per plant was higher under naturally ventilated polyhouse than shadow hall at all growth stages. The hybrid Indra showed maximum number of flowers per plant than Bomby. Among the interactions, Indra under polyhouse ( $S_1 \times H_3$ ) recorded maximum number of flowers per plant at 120 DAP.
6. The higher per cent of fruit set was noticed under naturally ventilated polyhouse than shadow hall. Among the hybrids, Indra recorded the maximum per cent of fruit set than Bomby. With regard to interactions Indra under polyhouse ( $S_1 \times H_3$ ) showed the higher extent of fruit set.
7. Number of fruits per plant was maximum under naturally ventilated polyhouse than shadow hall structure. The hybrid Indra recorded a higher number of fruits per plant than Bomby. Among the interactions, Indra under polyhouse ( $S_1 \times H_3$ ) recorded the highest numbers of fruits per plant at 120 DAP.
8. In case of quality parameters such as individual fruit weight and fruit volume, higher values were recorded under naturally ventilated polyhouse than shadow hall structure. With regard to hybrids, the Bomby showed higher fruit weight and volume at all harvesting stages. Among the interactions, Bomby under polyhouse ( $S_1 \times H_2$ ) recorded higher fruit weight and volume.
9. Pericarp thickness elicited moderate variation under different growing conditions. The maximum pericarp thickness was observed under naturally ventilated polyhouse than shadow hall. There was non significant difference among hybrids and their interactions.
10. The plants grown under naturally ventilated polyhouse showed a higher shelf life than shadow hall. The hybrid Indra showed higher shelf life than Orobelle. Among the interactions, the combination of Indra under polyhouse ( $S_1 \times H_3$ ) showed higher shelf life.

11. The higher yield per plant was noticed under naturally ventilated polyhouse than shadow hall. Among the hybrids, Indra recorded higher yield than Bomby. The interaction of Indra under polyhouse ( $S_1 \times H_3$ ) recorded higher yield.
12. The higher fruit yield per hectare was recorded under naturally ventilated polyhouse than shadow hall. Among the hybrids, Indra recorded higher yield than Bomby. The interaction combination of Indra under polyhouse ( $S_1 \times H_3$ ) recorded higher yield.
13. The maximum temperature was recorded under naturally ventilated polyhouse in the month of April and minimum temperature was recorded in shadow hall in the month of February.
14. The highest relative humidity was recorded under polyhouse in the month of August and minimum relative humidity was recorded under shade house with misting in the month of April.
15. The maximum light intensity was noticed under naturally ventilated polyhouse in the month of April and minimum light intensity was recorded in the month of August under shade house without misting.
16. The maximum rainfall was recorded in the month of June and no rainfall was recorded in the month of February.
17. The highest net returns and gross returns were obtained in the treatment combination of Indra under polyhouse ( $S_1 \times H_3$ ).
18. The total marketable yield was higher under naturally ventilated polyhouse.
19. The incidence of pests and diseases was lower under naturally ventilated polyhouse as compared to shadow hall structure and the higher incidence pests and diseases were noticed under shade house with misting.

#### Conclusion

In case of different growing environments, the naturally ventilated polyhouse recorded the highest total marketable fruit yield with more number of excellent quality export grade fruits. The capsicum cv. Indra gave a tremendous response to different growing structures. The lesser cost in case of shade house resulted in a higher benefit cost ratio as compared to naturally ventilated polyhouse. Instead of rainy season it can be grown very well in shade house structure. For common farmers the growing of capsicum cv. Indra under shade house structure will be more profitable.

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# EVALUATION OF CAPSICUM HYBRIDS UNDER DIFFERENT PROTECTED STRUCTURES

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## ABSTRACT

An experiment was carried out to study the performance of capsicum hybrids viz., Orobelle, Bomby and Indra under different protected structures like naturally ventilated polyhouse, naturally ventilated shadow hall, shadehouse with misting and shadehouse without misting during summer of 2007 at Hi-Tech Horticulture Unit, Department of horticulture, UAS , Dharwad.

The spacing followed was 45 x 60 cm (2.22plants/m<sup>2</sup>). The experiment was laid out in three factor strip plot design with three replications comprising of a total twelve treatments.

The results revealed that the quality parameters like fruit weight (160.00g), fruit volume (320.00 cc), rind thickness (0.91 cm) and shelf life (8.62 days) and yield parameters like number of fruits per plant (11.66), fruit yield per plant (3.62 kg), total fruit yield (72.52 t/ha) was significantly higher under naturally ventilated polyhouse than all other structures while naturally ventilated shadow hall recorded the least.

Among the different hybrids Bomby recorded significantly higher fruit weight (158.50g), fruit volume (310.00 cc) and shelf life (8.60 days) and there was non significant difference among the hybrids with respect to rind thickness. The maximum fruit yield per plant (2.63 kg) and fruit yield per hectare (58.49 t) was recorded by Indra.

With respect to the interactions, the highest fruit weight (173.00 g/fruit), fruit volume (346.00 cc/fruit) were recorded by Bomby grown under naturally ventilated polyhouse (S<sub>1</sub>H<sub>2</sub>). There was non significant difference with respect to rind thickness and higher shelf life (9.01 days) was recorded by Indra grown under naturally ventilated polyhouse (S<sub>1</sub>H<sub>3</sub>). The maximum fruit yield (3.43 kg/plant) and fruit yield per hectare (76.22 t) were recorded by Indra grown under naturally ventilated polyhouse (S<sub>1</sub>H<sub>3</sub>).