

**PERFORMANCE OF SWEET PEPPER  
(Capsicum annum L.) CULTIVARS AND ECONOMICS  
UNDER PROTECTED STRUCTURES IN PUNJAB**

A  
Thesis  
Submitted to



For the award of  
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in  
**VEGETABLE SCIENCE**

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## DECLARATION

I hereby declare that the thesis entitled, “**Performance of sweet pepper (*Capsicum annuum* L.) cultivars and economics under protected structures in Punjab**” submitted for the degree of Doctor of Philosophy, in the subject of **Vegetable Science** to the School of Agriculture, Lovely Professional University is entirely original work and all ideas and references had been duly acknowledged. The research work had not been formed the basis for the award of any other degree.

Daljit Singh Gill

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### CERTIFICATE

This is to certify that **Mr. Daljit Singh Gill** had completed the Ph.D. Vegetable Science, entitled “**Performance of sweet pepper (*Capsicum annuum* L.) cultivars and economics under protected structures in Punjab**” under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of this thesis had ever been submitted for any other degree or diploma.

The thesis is fit for the submission for the partial fulfilment of the condition for the award of degree of Ph.D. in Vegetable Science.

Signature of Supervisor

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**Title of the thesis** : Performance of Sweet pepper (*Capsicum annuum* L.) cultivars and economics under protected structures in Punjab

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### **ABSTRACT**

The study entitled ‘Performance of Sweet pepper (*Capsicum annuum* L.) cultivars and economics under protected structures in Punjab’ was carried out under different protected structures, i.e., naturally ventilated polyhouse (NVPH), net-house and walk-in tunnel (WIT) for the two consecutive cropping seasons of 2014-15 and 2015-16 at Centre of Excellence for Vegetables, Kartarpur, Jalandhar (Pb). The experiment was laid out in split plot design having protected structures as main plot treatment and different capsicum hybrids i.e. green colour (Indra, Pasrella, and Starlet), red colour (Inspiration, Bomby, and Mazillia), and yellow colour (Orabelle, Bachata, and Sven) as sub-plot treatment separately with three replications each. With respect to vegetative growth, reproductive phase and fruit yield related parameters the experimental results revealed that the plants grown under NVPH conditions had maximum plant height, fruit set percentage, number of fruits per plant, individual fruit weight, total fruit yield per plant, whereas early flowering and harvesting in all the three different colour groups of capsicum under walk-in-tunnel conditions. Among green coloured capsicums maximum profitability was recorded with Indra in terms of first flower initiation (41.93 days), number of fruits per plant (21.49), total yield per plant (3.62 kg) and total fruit yield per m<sup>2</sup> (10.86 kg) over the hybrids Pasrella and Starlet. In red colour group, early first flowering (42.33 days), first fruit harvest (105.83 days), maximum individual fruit weight (216.53 g), and total yield per plant (2.81 kg) was recorded in hybrid Inspiration as compared to hybrids Bomby and Mazillia. Similarly, hybrid Bachata had shown early first flower initiation (44.93 days), first fruit harvest (98.19 days), maximum plant height (113.06 cm), percent

fruit set (41.83), individual fruit weight (190.73 g), total fruit yield per plant (3.0 kg) over hybrids Orobelle and Sven in the yellow colour group.

All the fruit quality parameters under study were significantly influenced by the protected structures along with their interaction effects. Among structures, NVPH cultivation recorded higher fruit rind thickness, fruit volume and fruit shelf life, whereas, WIT structure had a great influence on fruit length and fruit diameter for all of the green, red, and yellow coloured group hybrids. The green group hybrid Indra had maximum fruit length (9.70 cm), fruit diameter (7.50 cm), fruit shelf life (8.59) as compared to hybrid Pasrella and Starlet in their respective group. The red group hybrid namely Inspiration was recorded best for fruit length (9.70 cm), fruit diameter (8.23 cm), fruit volume (434 cc), fruit rind thickness (0.89 cm), and shelf life (8.0 days) as compared to hybrids Bomby and Mazillia. The yellow group hybrid Bachata recorded maximum fruit length (9.03 cm), fruit volume (388.66 cm), and fruit rind thickness (0.90 cm) as compared to hybrids Orobelle and Sven.

The results further revealed that among green coloured hybrids, Indra had higher net returns of Rs. 65740/- from an area of 500 m<sup>2</sup> under the NVPH which resulted in highest B:C ratio of 1:1.53. Among red colour hybrids, Inspiration had higher net returns of Rs. 80190/- under NVPH and also had the highest B:C ratio 1:1.61 for this colour group. Among the yellow coloured group hybrids, Bachata resulted in maximum net returns of Rs. 93940/- under NVPH. However, Bachata gave maximum B:C ratio of 1:1.75 under walk-in-tunnel followed by NVPH having B:C ratio 1:1.72.

It is, therefore, concluded that the naturally ventilated polyhouse (NVPH) showed its superiority as compared to net-house and walk-in-tunnel (WIT) for the cultivation of green, red and yellow coloured group hybrids for commercial production. It is also concluded that the Indra, Inspiration, and Bachata ranked first among green, red, and yellow colour group respectively for cultivation under protected structures for getting higher net returns per unit area under Punjab conditions.

**Key words:** Capsicum, protected cultivation, hybrids, polyhouse, net-house, walk-in-tunnel

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## **CHAPTER – I**

### **INTRODUCTION**

*Capsicum annuum* L., commonly called as peppers, belongs to botanical family Solanaceae. It is grown all over 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 two groups viz. sweet and hot type on the basis of pungency content. The bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.) is commonly known as sweet pepper, capsicum or green pepper. It is well adopted to temperate part of American and European countries while tropical or sub-tropical parts of Asian countries. It is a high productivity crop and has high remunerative value.

Global vegetable production amounted to a total of 956 million tonnes and had grown up by 56% in the last decade. India is the second largest producers of vegetables in the world next to China with an estimated production of about 126.58 million tonnes from an area of 8.51 million hectares with an average yield of 14.87 tonnes per hectares (Anonymous 2017). India shares about 15% of the world output of vegetables from about 4% of cropped area in the country (Anonymous 2014). Capsicum was grown on an area of 46 thousand hectare with annual production of 288 thousand MT in India. In Punjab it was grown on an area of 0.31 thousand hectare with annual production of 4.81 thousand MT during the year 2015-16 (Anonymous 2017). However, in India per capita consumption of vegetables is 210 g/day, which is very low against WHO standards of per capita requirement of 300 g/day vegetables as recommended by FAO (Dhaliwal, 2014).

Nutritionally 100 g of capsicum provides 8493 IU of Vitamin A, 283mg of Vitamin C, 13.4 mg of Ca, 14.9 mg of Mg, 28.3 mg of P, 263.7 mg of K, 24 Kcal of energy, 1.3 g of protein, 4.3 g of carbohydrate and 0.3 g of fat (Yellavva, 2008). It is widely used as vegetables, cooked or preparation of pizza or burger in growing fast food chain. Its high consumer demand is attributed with high market price.

Capsicum can be successfully grown under open field conditions and in protected structures, i.e., net house, polyhouse, walk-in-tunnels, plastic low tunnels, etc. (Singh and Sirohi 2006) but its cultivation under open condition is not successful

which might be due to poor adoptability under fluctuating atmosphere and produced poor quality food under erratic biotic and abiotic factors (Yoon *et al.* 1989; Kanwar *et al.* 2014). The cultivation of capsicum under different protected structures like polyhouse, net house, walk-in-tunnels, plastic low tunnels are the most suitable solutions to the challenging environmental factors as it prevents spreading of insect, pest, and viral diseases, hence plays a key role in integrated pest management.

Worldwide total greenhouse area is the maximum in China at 2760 thousand hectare followed by Korea 57.4 thousand hectare (Anonymous, 2018). In India, the area under all forms of protected cultivation is nearly 25 thousand hectare however significant efforts are being made under National Horticulture Mission, Ministry of Agriculture, Government of India to increase area under protected cultivation (Anonymous, 2012). In Punjab upto 2016-17, total number of 1151 protected structure units (all types) were established which covered an area of 224 hectare under protected cultivation (Anonymous, 2018).

The growing trend of protected cultivation is associated with high yield, good quality, improved shelf life and year around availability of pepper fruit (Rai *et al.* 2004). Greenhouse technology can be utilized for controlling the environmental parameters such as temperature, relative humidity, light intensity and duration, CO<sub>2</sub> level, Irrigation & nutrient supply, spacing, growing medium and root development (Baghel *et al* 2003; Wani *et al* 2011). Choudhary (2016) reported a manifold increase in the resource-use efficiency through crop cultivation under protected structures as compared to the open-field conditions. The high-value cash crops and vegetables are grown and managed under the controlled environmental conditions with higher productivity/unit of area and economic profitability.

Among the various protected structures, polyhouse production had been proven as more profitable protected technique for capsicum cultivation (Aruna and Sudagar 2010). Polyhouse/greenhouse production of capsicum emphasizes appropriate planting densities to boost-up the total production per unit area by utilizing the space available and nutrient applied.

Now-a-days, decreasing land holding for crop cultivation hinders the availability of land under vegetable crops, further year around availability of good quality capsicum endorses the cultivation of capsicum under protected environmental

conditions such as greenhouse or polyhouse. Protected cultivation also ensures the availability of produce in the market during off season, when it is in great demand.

The northern plains of India had very fertile soil, enriched with natural macro and micro nutrients essential for crop cultivation. But the vegetable cultivation is confined to region specific and season specific due to varied climatic conditions. The extremes of temperature range from 0°C to 48°C prevails in northern plains, which restrict year-round production of capsicum to meet the daily requirement. Thus, protected cultivation delimits the vagaries of extreme of adverse climatic conditions. It is well known fact that protected cultivations has so many advantages like early fruit yield, high yield per unit area, excellent marketable quality of produce on demand, year round production of capsicum, better utilization of land and space, minimum use of ground water by using drip irrigation system, controlled environmental conditions like temperature, humidity and light, eco-friendly use of inorganic chemical like fertilizers and pesticide, management of biotic and abiotic stresses, more scope to adopt bio-solutions to control biotic and abiotic stress etc.

Although some capsicum cultivars like Orobelle, Indra, Bomby had been tested for protected cultivation in net house or shadenet etc., but many other good cultivars are now available, which need to be tested for their cultivation in Punjab state under different types of protected structures such as naturally ventilated polyhouse (NVPH), walk-in-tunnel (WIT), Nethouse etc. Thus a study was planned with the following objectives in view:

- To evaluate capsicum cultivars under different protected structures.
- To study the effect and economics of different protected structures on capsicum cultivation.
- To work out technology for year-round production of capsicum.

## **CHAPTER – II**

### **REVIEW OF LITERATURE**

So far, the efforts in vegetable crops were restricted to the development of high yielding varieties and hybrids for open field conditions. Despite its economic importance the productivity of crop under open field condition was adversely affected by harsh weather conditions. Protected cultivation expanded very rapidly in many regions of the world with the introduction of plasticulture in the field of agriculture. The protected cultivation had the main objective of crop protection against adverse climatic conditions. But now-a-days due to environmental impact, good quality produce and safe vegetable produce are attracting consumer's demand. Therefore, there is an urgent need to evaluate the performance of different capsicum hybrids and varieties under protected environmental conditions. The literature pertaining to the present study entitled "Performance of Sweet pepper (*Capsicum annuum* L.) cultivars and economics under protected structures in Punjab" is reviewed here as under:

#### **2.1 Protected Structures**

Basavaraja *et al* (2003) reported that the higher yield obtained from the polyhouse was due to the favourable weather conditions, i.e., air temperature, relative humidity and light intensity present in the growing structure, which influenced good vegetative and reproductive characters in capsicum. The interaction effect between growing environment and nutrients supply and uptake was found to be significant, indicating a favourable influence of these two parameters on growth and fruit yield of the sweet pepper crop.

Murthy *et al* (2009) have confirmed the significance of protected cultivation of capsicum due to its economic viability, high yield, better fruit quality, superior fruit appearance and ensured availability of capsicum throughout the year. They have further endorsed the promotion of this technology should be regulated by government and non-government institutions.

Singh and Sirohi (2006) had emphasized over the use of low cost protected structures like low plastic tunnels or walk-in-tunnels or shade net houses for off-season nursery production, small scale production of vegetables to fetch high price,

virus free and insect free development of nursery in rainy season and good quality production of sweet pepper during rainy and post-rainy season.

Tunnel farming is one of the modified techniques of plastic-culture of modern farming. Tunnel farming was started first in 1948; it is a cheapest form of greenhouse. Later on, more operational and economical forms of tunnel farming were introduced. The Plastic tunnels had diverse mechanism as tunnels are not heated-up artificially and are operative under minimum environment control as compared to greenhouses. Tunnels are more cost-effective than the greenhouses (Fatima *et al* 2017).

Takte *et al* (2003) have used plastic films and shade nets in order to protect high value crops against various stresses like extreme atmosphere and insect-pests. Further, they added that ventilation played an important role in crop production under controlled conditions.

Medany *et al* (2009) concluded that black net greenhouse gave significantly the highest early crop yield, while white net greenhouse significantly contribute to the highest plant height, number of leaves per plant, leaf area index and total fruit yield as compared to the other greenhouses.

Ilic *et al* (2011) have reported 113 – 131% of yield of bell pepper grown under pearl, red, blue or black coloured shadenets with shading of 40% or 50% in comparison to open cultivation.

Ombodi *et al* (2015) had reported 23 – 39% of decrease in incoming radiation and 32 – 46% reduction in PAR under shade nets of white, green, yellow or red colour. However, yellow and green shade nets decreased yield while white shade nets in green house was reported best under unfavourable conditions

## **2.2 Growing Media**

Gungor and Yildirim (2013) used growing mixture as peat:perlite:sand (1:1:1 v:v:v) in polythene bags to study their effect on different qualitative and quantitative characters of capsicum grown under greenhouse conditions. A significant improvement in fruit size and weight was reported when mixture was used as media while Vitamin C, Total Soluble Solids (TSS), fruit count and yield was highest when peat was used as media.



### **2.3 Effect of Protected Structures on Capsicum**

Maurer (1981) reported that the bell pepper cultivars 'Newace' and 'Early prolific' had higher per plant fruit yield as compared to other cultivars under partially environment controlled greenhouse during off-season cultivation.

Buoczkowska (1990) reported early fruiting and higher marketable yield of sweet pepper (4.62 kg/m<sup>2</sup>) under plastic cover in comparison to open field conditions (3.40 kg/m<sup>2</sup>). Similar findings were reported by Seekar and Hochmuth (1994) with the view that plants under polytunnel resulted higher fruit yield (98.00 t/ha) as compared to open field conditions (68.00 t/ha). Similarly, total soluble solids (TSS) and Vitamin C content of capsicum fruit under polyhouse was also higher in comparison to open field conditions (Jeevansab, 2000).

Rai *et al* (1992) reported the longer shelf life of produce harvested from six hybrids grown under polyhouse as compared to open conditions. The maximum shelf life of 16 days was recorded in hybrid Arun growing in polyhouse, while it had only 10 days shelf life of fruits harvested under open conditions.

Megharaja (2000) compared performance of Indra cultivar of capsicum under polyhouse and open condition and reported significantly high plant height (94.36 cm), branching (31.94 branches per plant), fruit count (12.08 fruits per plant), fruit size (8.54 cm x 6.76 cm), fruit weight (120.06 g), fruit volume (255.97 cc) and fruit yield under polyhouse condition over open conditions.

Bell pepper grown using polyethylene mulch and mini tunnels had shown larger and more productive fruit with thicker pericarp and higher water content (Bowen and Frey 2002). Brar *et al* (2005) reported highest crop yield of 242q per hectare in Capsicum var. Bomby under polyhouse condition with the effect of trickle irrigation system in pune region.

Naik (2005) reported that among three growing conditions namely medium cost polyhouse, low cost polyhouse and net house, the medium cost polyhouse recorded higher fruit yield of capsicums. The favourable environmental conditions prevailing in medium cost polyhouse might had helped in better growth of roots and shoots, which directly helped in better vegetative growth and finally improving the yield attributing parametres *viz.*, number of fruits per plant (10.29), fruit weight per plant

(1.02 kg), pericarp thickness at blossom end (1.23 cm), fruit length (8.49cm) and fruit breadth (7.24) and these finally led to highest total yield of 37.77 MT per ha.

Sood and Kaul (2006) reported the number of fruits per plant in bell pepper, which had also direct effect on fruit yield, ranged from 20.33 to 52.00 fruits per plant. All the fifteen hybrids exhibited more fruits than the standard check Anupam, but only one hybrid California Wonder X Kandaghat Selection with 24.66 fruits was significantly superior to better parent.

Singh *et al* (2007) reported fruit yield of 6.5 kg/m<sup>2</sup> with average fruit weight of 54g, in California Wonder transplanted in March under naturally ventilated polyhouse whereas it was negligible when grown under open field conditions.

Kurubetta and Patil (2009) studied the performance of capsicum hybrids, i.e., Orobelle, Bomby and Indra under naturally ventilated polyhouse (NVPH), naturally ventilated shadowhall. The quantitative parameters like earliest flower initiation (33.00 days), first fruit harvesting (86.00 days) and highest fruit set (49.81%) and the quality parameters like fruit weight (160.00 g), fruit volume (320.00 cc), rind thickness (0.91 cm) and shelf life (8.62 days) were significantly maximum under naturally ventilated polyhouse than naturally ventilated shadowhall. Among the hybrids, Bomby recorded higher fruit weight (158.50 g), fruit volume (310.00 cc) while Indra recorded higher rind thickness (0.87 cm) and shelf life (8.60 days).

Kanwar and Sharma (2010) evaluated performance of capsicum hybrids and recommended hybrid Bharat, BSS-519 and Spinx which performed best under greenhouse conditions in the cold arid region of Ladakh. There were no significant differences observed for the plant characters like plant height, number of fruits per plant and days to first harvest, however hybrid Bharat was earliest for marketable yield and had longest fruit span.

Singh *et al* (2011) concluded that protected conditions enhanced production of sweet pepper as compared to open fields, particularly during rainy and off-season. They recorded maximum crop duration (270 days) in sweet pepper under polyhouse conditions, (180 days) in poly tunnel, (150 days) along with poly-mulching as compare to (117 days) in open field condition along with maximum fruit diameter (6.91 cm), maximum number of fruits per plant (47), highest individual fruit weight

(62.17 g), average fruits weight (2.91 kg/plant), yield (17.48 kg/m<sup>2</sup>) followed by poly-tunnel and plastic-mulching treatments, respectively.

The suitability of a low-tech naturally ventilated greenhouse for cultivation of capsicum in warm and humid climate was evaluated by Ghosal and Das (2012). They have observed that the yield of capsicum per square metre in the greenhouse was found to be 2.34 times more than open field condition. Moreover, Overall growth of capsicum in terms of plant height and number of leaves per plant in the greenhouse was more in low cost NVPH as compared to the open field conditions. Early flowering and fruiting were also observed in the greenhouse condition. The benefit:cost ratio for capsicum in the greenhouse was 2.98, whereas it was 0.80 in case of open field condition.

Singh *et al* (2013) studied the impact of low plastic perforated tunnel, low plastic non-perforated tunnel on performance of bell pepper in comparison with open conditions. The early fruit yield (68.7 q/ha), total fruit yield (278.2 q/ha), fruit number per plant (18.9), plant height (49.44 cm) and fruit girth (33.17 cm) were significantly higher in low plastic non-perforated tunnel as compared to open conditions.

Halim and Islam (2013) studied the performance of capsicum variety California Wonder under four different protective structures, i.e., low height poly tunnel, poly tunnel with side open, poly tunnel with side closed and poly house and open field conditions. Significant influence of protected structures was recorded on plant growth and fruit yield of capsicum with higher plant height compared to open field. The highest individual fruit weight (65.2g) was recorded under poly house condition as compared to lowest under open field (3.34 g). Maximum fruit yield per plant (334.0g) was recorded under poly house, which was 160.4% higher than that of open field condition followed by the second highest fruit yield which was recorded under poly tunnel (212.5) influencing pepper cultivation under protective structures.

Swamy (2013) evaluated different capsicum hybrids for growth and yield parameters under 50% shade net and postulated that the hybrid Indra possessed maximum plant height (130.17cm), maximum number of primary and secondary branches (5.93 and 5.34 respectively), lowest days taken for first flower initiation (36.28 days), first fruit picking (76.14 days), fruit length (10.42 cm), maximum fruit

width (8.03 cm), fruit volume (313.36 cc), fruit wall thickness (1.05 cm), maximum number of fruits per plant (17.00), maximum individual fruit weight (124.70g).

The effect of spacing and training system on capsicum production under NVPH having three plant spacings, i.e., 30 x 45, 45 x 45 and 60 x 45 cm and three training systems, i.e., two shoots, three shoots and unpruned was studied by Lone (2014). The results revealed that wider spacing of 60 x 45 cm showed early flower initiation (35.6 days), early fruit setting (50.3 days) and early first picking (68.6 days), higher fruit length (8.2 cm), fruit breadth (7.8 cm), fruit weight (92.7 g), shelf life (8.6 days), pericarp thickness (0.78 cm), number of fruits per plant (21.1) and fruit yield per plant (1.8 kg) than other two plant spacings. However, maximum fruit yield (844.0kg/100m<sup>2</sup>) was recorded under closer spacing of 30 x 45 cm. With respect to the pruning of plants, two shoots per plant recorded significantly higher fruit length (8.3 cm), fruit breadth (7.7 cm), fruit weight (92.4 g), pericarp thickness (0.79 cm), shelf life (8.5 days). He also reported that plants spaced at 30 x 45 cm showed maximum net returns (Rs. 16525) and benefit: cost ratio (1:1.39) followed by three shoots per plants with 45 x 45 cm plant spacing (Rs.15369 and 1:1.31). The lowest net returns and benefit: cost ratio (Rs.8184 and 0.71) were registered from unpruned plants.

Farooq *et al* (2015) investigated the growth and fruit yield of five capsicum hybrids namely Orobelle, Figaro, Green Beauty, Mighty, Capistrano with Yelowonder as control grown under plastic tunnel and the observations were made for number of fruits per plant, fruit weight per plant (kg), length of fruits (cm), diameter of fruits (cm), pericarp thickness (mm), number of locules per plant and fruit yield (t/ha). Among five hybrids Orobelle ranked first for number of fruit per plant (43.47), fruit weight per plant (1.96 kg) and fruit yield (51 t/ha) followed by hybrids Figaro (32.84, 1.72 kg, 48.57 t/ha) and Capistrano (41.48, 1.76 kg, 45.90 t/ha), respectively. However, Mighty hybrid was investigated with highest fruit length and fruit diameter (5.98, 6.27 cm), respectively.

The comparative effect of growing conditions, i.e., open field and polyhouse, three planting dates (15 October, 30 October, and 15 November), and four mulch treatments (black polythene, clear polythene, paddy straw, and no-mulch) on growth and yield of capsicum was investigated by Dhaliwal *et al* (2017). Maximum number

of fruits, fruit weight, early fruit yield, marketable fruit yield, and total fruit yield were obtained in the polyhouse when the crop was planted on 30 October along with black polythene mulch. Therefore, they concluded that the polyhouse cultivation and black plastic mulch, when combined with appropriate planting date, early and total yields of capsicum was improved.

#### **2.4 Effect of Protected Structures on Other Vegetables**

The higher yield in polyhouse, polytunnel technologies might also be due to improved climate condition in these structures. In polyhouse the temperature was found to be 3–4°C higher than open condition, however in polytunnel the temperature was found to be 1–2°C higher than polyhouse. More *et al* (1990) reported that cucumber variety 'Poinset' gave a higher fruit yield of 1.70 kg per plant under polyhouse condition as compared to lower fruit yield of 0.75kg per plant in open field conditions, during winter months under North Indian conditions due to low temperature.

The higher productivity of tomato (93.20 t/ha) and capsicum (76.40 t/ha) inside greenhouse was observed by Singh *et al* (2005). They reported that it was mainly because of higher temperature (4–9°C) than the outside observed during month of December to February and high rate of utilization of carbon-dioxide inside greenhouse.

Bhatia *et al* (2007) investigated the performance of muskmelon hybrids/varieties in greenhouse for growth and yield related characters and recommended the best hybrids for cultivation in this structure on the basis of observations recorded for early first fruit harvest, number of fruits per plant, average weight of individual fruit, flesh thickness and fruit yield.

Hebbar *et al* (2013) evaluated performance of different muskmelon hybrids in naturally-ventilated polyhouse in winter season. They concluded 123 per cent increase in mean yield (63.6 tonnes/ha) in all hybrids over the open field conditions (28.6 tonnes/ha) and significantly higher fruit weight and TSS under polyhouse grown fruits compared to open conditions.

Koley *et al* (2013) investigated quality parametres of tomato under protected and open cultivation and found significant higher lycopene, vitamin C and antioxidant

activity (FRAP) in the fruit produced under protected structures at full ripe stage over the open field cultivation.

Higher and profitable yield of green leaves of coriander in off-season under protected environment, i.e., insect-proof net tunnel, green shade net, black shade net, walk-in-tunnel was recorded in comparison to open field condition (Lal *et al*, 2013).

## **2.5 Planting Densities under Protected Structures**

Dasgan and Abak (2003) reported that a spacing of 80 × 30 cm between row to row and plant to plant, respectively with three shoots per plant was more economical for cultivation of capsicum under glasshouse. They also observed that the fruit quality parameters such as fruit weight, fruit length, fruit diameter, fruit volume, fruit dry matter, TSS and pH of flesh were not significantly influenced by plant density and number of shoots per plant.

Lee and Liao (2007) reported that the SRC (sugarcane residue compost substrate) was used as substrate basket culture of sweet pepper to compare the training method of single stem, double stem and no training at the densities of four to six plants in each basket in the following experiment. The highest marketable fruit yield (49,952 kg/ha) was achieved by double-stem training at a density of six plants per basket resulted in higher proportion of large sized fruits.

Mantur *et al* (2007) reported that capsicum fruit yield, numbers of fruits per plant with high mean fruit weight were significantly more when planted at a spacing of 45 × 30 cm compared to a relatively wider spacing of 45 × 45 cm during summer season.

Zende (2008) had studied response of Orobelle cultivation against different growing condition, spacing and training practices and had reported that close spacing (45 cm x 30 cm) and 4 shoots training practices was most economical in capsicum however spacing of 45 cm x 45 cm with 3 shoots training practices were provided highest yield. Further, capsicum grown under polyhouse condition (NVPH) have resulted highest marketable fruit yield with excellent and export grade fruit quality. He had also confirmed highest benefit: cost ratio with spacing of 45 cm x 30 cm under NVPH and was most profitable for farmers in summer season. Similarly, Kumar and Chandra (2014) had also reported greater flower count, fruit count and yield of Indra hybrid of capsicum under polyhouse condition under different spacing, however in

comparison to 45 cm x 30 cm of spacing with 4 shoot per plant training levels, closer spacing 45 cm x 30 cm was most profitable option.

## **2.6 Irrigation and Fertigation under Protected Structures**

Silber *et al* (2003) had reported positive correlation between plant yield with number of fertigation of low concentration which might be due to enhanced uptake of nutrient, primarily due to Phosphorus as the high fertigation frequency might overcome for nutrient deficiency (Xu *et al.* 2004).

Silber *et al* (2005) also examined fertigation frequency on the occurrence of plant disease and reported that increased fertigation frequency reduced blossom end rot disease incidence in capsicum.

Kumar and Verma (2009) had explored suitability of low cost NVPH for year around production of capsicum. They have further reported application of 250 kg of water soluble fertilizers (NPK) per hectare as fertigation in combination with black polythene mulching was most suitable for off-season capsicum production under protected condition as it was reported with maximum plant height, flower count, fruit count, fruit set percent and yield per plant or per square metre.

Lal and Kanaujia (2013) conducted integrated nutrient management study on growth, fruit yield and quality of capsicum cv. California Wonder under low cost polyhouse. The maximum plant height (54.46 cm), number of leaves per plant (38.89), number of fruits per plant (10.48), fruit weight (85.06g), fruit length (8.56 cm), fruit diameter (5.63 cm), fruit yield (29.70 t/ha) were recorded with the application of 50% NPK + 50% FYM+ biofertilizer and had higher net returns with cost:benefit ratio of 1:8.16.

Ima-obong *et al* (2017) studied the growth and yield responses of green pepper to varying levels of manures under high tunnels and open field conditions. The findings showed that the 5 t/ha of poultry manure and 200 kg of NPK produced the highest total fruit yield, plant height, more number of branches per plant. High tunnel produced 3.1 fruits per plant having 102.8 g average fruit weight, which was higher than the open field conditions in which 1.7 fruits per plants having 32.3 g average fruit weight were obtained. Moreover, in the rainy season high tunnel enhanced the pepper production as compared to open field conditions which was near failure as the

open field conditions did not protect the crop against heavy rainfall, hails, cold wind and high humidity but also promoted disease, i.e., bacterial wilt in plant and fruits (Singh *et al.* 2005).

## **2.7 Insect-Pest Infestation under Protected Conditions**

Yosepha *et al* (2007) observed that all sweet pepper cultivars showed more productivity under photoselective shading, as there was an increase in number of fruits per plant by 30 to 40 per cent compared to the use of common black net. Different coloured nets were used for photoselective shading and it was found that the red net had some productivity advantage over the pale and yellow nets. The risk of disease infestation by small insects like aphids, thrips and the incidence of insect borne viral diseases were recorded significantly lower under yellow net as compared to all other nets.

Kaur *et al* (2010) studied that thrips and mites were serious pests on sweet pepper. The root-knot nematode population was not recorded at the time of transplanting in most net houses, but gradually increased over the growing season in capsicum. They also revealed that the farmers applied prophylactic insecticide sprays to manage sucking insect-pests in nethouse.

Anwar *et al* (2013) conducted a survey to determine the occurrence of plant-parasitic nematodes on vegetable crops, i.e., cucumber, tomato, chili and bell peppers grown in plastic tunnels. The presence of nine species of plant-parasitic nematodes viz., *Aphelenchus avenae*, *Helicotylenchus dihystra*, *Hoplolaimus columbus*, *Meloidogyne javanica*, *M. incognita*, *Pratylenchus penetrans*, *Radopholus similis*, *Tylenchorhynchus claytoni* and *Xiphinema* sp. were recorded. Un-uniform foliage growth, stunted growth, chlorotic leaves and wilted plants in patches were observed under the tunnels where the vegetables were grown. The infestation of nematodes in tunnel grown vegetables needed significant control measures to tackle nematode infestation by the use of integrated pest management strategies.

## **2.8 Economic Returns under Protected Structures**

Singh *et al* (2004) concluded that protected cultivation of capsicum under nethouse created favourable atmosphere for consistent plant growth, early and prolonged production. Further, this practice is suitable for small land holdings or fragmented



land holdings to provide high profit. Among 7 hybrids of capsicum tested under controlled condition, Bharat was reported with high fruit yield, uniform fruit size, quality fruit due to management of insect pest by nonchemical technique under protected structures.

Sreedhara *et al* (2013) performed protected cultivation of capsicum and has reported high cost of establishment, fruit yield [5.50 tons/unit (0.25 acre)], total returns (Rs. 1,54,734/- per unit), net returns (Rs. 1,15,279/- per unit) and B:C ratio (3.92).

Galinato and Miles (2013) had reported 5-times more cost invested for lettuce cultivation under high tunnel and 8-times for tomato cultivation when compared with open cultivation while yield was 3 and 4 times higher under tunnel grown lettuce and tomato respectively. This was further confirmed that cultivation of lettuce under open condition was 43 % more profitable and tunnel based cultivation of tomato was 3-times profitable.

Kumar *et al* (2016) conducted economic studies on capsicum cultivation under polyhouse and open field conditions and concluded that due to higher yield (145%) of capsicum under polyhouse conditions than the open field conditions, the net returns/acre of the crop was 208 percent higher than the open field conditions.

A split-plot experiment is a blocked experiment, where the blocks themselves serve as experimental units for a subset of the factors. Thus, there are two levels of experimental units. The block is referred to as main plot, while the experimental unit within blocks are called split plot, split unit, or subplot. Split-plot designs were originally developed by Fisher (1925) for use in agricultural experiments. The cost of running a set of treatments in split plot order is generally less than the cost of the same experiment when under completely randomized design. Split-plot experiments are not just less expensive to run than completely randomized experiments and are statistically more efficient (Jones and Nachteim 2009).

## **CHAPTER – III**

### **MATERIALS AND METHODS**

The present investigation entitled, ‘Performance of Sweet pepper (*Capsicum annuum* L.) cultivars and economics under protected structures in Punjab’ was carried out for the two consecutive cropping seasons of 2014-15 and 2015-16 under Naturally Ventilated Polyhouse, Nethouse and walk-in tunnel at Centre of Excellence for Vegetables (An Indo-Israel project), Kartarpur, Jalandhar (Pb).

#### **3.1 Geographical Location**

Kartarpur (Jalandhar) is located at 31.44<sup>0</sup> N (latitude) and 75.5<sup>0</sup> E (longitude) at the altitude of 228 m above sea level.

#### **3.2 Climate**

Kartarpur (Jalandhar) had a humid sub-tropical climate having hot summers associated with desiccating winds during April-June followed by hot-humid rainy season and cold winters with occasional ground frost in December-January. The average annual rainfall of the region is 1110.7 mm

#### **3.3 Methodology**

Nursery of the crop was raised using black plastic pro-trays of 99 cells or cavities in polyhouse in SLCM (soilless culture media) during August 2014 and seedlings were transplanted during September 2014 for the first season 2014-15 (Sept - May); and in August 2015 and seedlings were transplanted during September 2015 for the second season 2015-16 (Sept - May).

Soilless culture media for nursery raising was prepared by using coco peat: vermiculite: perlite (v/v) in the ratio 3:1:1 (v/v). Cocopeat was soaked in water for 12 hours before mixing. The pH value of 6.5 was recorded for coco peat media. The cavities of black plastic pro-trays were filled with the growing media and the one seed per cavity was sown and covered with media. A thin layer of vermiculite was spread over the plastic tray cavities to check the water loss through evaporation for better germination of seeds. The seeds were germinated in 9-10 days after sowing.

***Fertigation schedule (Nursery)***

Nursery stage	Component name	Dose	Mode of application
8-10 days after germination	N.P.K (19:19:19)	2 g / litre	Root drenching
Once in a week	Captan/Bavistan	1 g / litre	Root drenching
15-20 days after	Calcium Nitrate/ Magnesium sulphate	1 g / litre	Root drenching

For transplanting of seedlings under the different protected structures; the experiment was laid out in split plot design keeping naturally ventilated polyhouse (NVPH), nethouse and walk-in-tunnel (WIT) as main plots and different hybrids of following groups as sub plot treatments.

- I. Green coloured sweet pepper hybrids: Indra, Pasrella, and starlet
- II. Yellow coloured sweet pepper hybrids: Bomby, Inspiration, and Mazillia
- III. Red coloured sweet pepper hybrids: Orobelle, Bachata, and Sven

***Lay out design of experiment***

Structure ↓	Replication – I			Replication – II			Replication – III		
	Green	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow
Capsicum →									
Naturally	G1	R1	Y1	G2	R3	Y2	G3	R2	Y1
Ventilated	G2	R2	Y2	G1	R1	Y3	G2	R1	Y3
PolyHouse (NVPH)	G3	R3	Y3	G3	R2	Y1	G1	R3	Y2
Nethouse	G1	R1	Y1	G2	R1	Y2	G3	R2	Y1
	G2	R2	Y2	G3	R3	Y3	G1	R3	Y2
	G3	R3	Y3	G1	R2	Y1	G2	R1	Y3
Walk- in- Tunnel (WIT)	G1	R1	Y1	G1	R2	Y1	G2	R3	Y2
	G2	R2	Y2	G2	R1	Y3	G1	R1	Y3
	G3	R3	Y3	G3	R3	Y2	G3	R2	Y1

**Note :**

- G1, G2 and G3 represented Green coloured hybrids of Capsicum, i.e., Indra, Pasrella, and starlet respectively.
- R1, R2 and R3 represented Red coloured hybrid of Capsicum, i.e., Bomby, Inspiration, and Mazillia respectively.
- Y1, Y2 and Y3 represented Yellow coloured hybrid of Capsicum, i.e., Orobelle, Bachata, and Sven.

***Soil Preparation***

The soil was ploughed using rotary tiller and covered with white polythene sheet (30 micron) for soil solarisation/soil sterilization. The soil was irrigated by drip system of irrigation after every 2<sup>nd</sup> day for 30 minutes up to 4-5 weeks to maintain moisture in the soil. The soil was treated to destroy the insect-pest and disease pathogens that persisted in the soil during June month.

***Bed preparation***

The beds were prepared at the distance of 2 metre (from center of 1<sup>st</sup> bed to the center of 2<sup>nd</sup> bed). The beds having 80 cm wide base and 45 cm wide top were prepared. The 35-40 days old seedlings were transplanted on the beds with 40 x 30 cm plant to plant and row to row spacing respectively.

***Mulching***

Mulching was done by using silver black polythene sheet of 30 micron thickness for the management of unwanted weeds and to conserve soil moisture. It is also helpful in maintaining the soil temperature of bed in December and January.

From the beginning of flower initiation to fruit setting boron @ 1-2 g per litre of water was sprayed twice with the interval of 10 days. Other recommended cultural operations were carried out according to the crop requirement as per the improved package of practices for cultivation. Fertigation schedule (after transplanting) is as per Table.

### Fertigation schedule (after transplanting)

With 15 minutes of drip irrigation		Fertilizers (kg/acre) on weekly basis						
Stage	Duration Days	NPK 19:19:19	NPK 12:61:0	Calcium Nitrate	NPK 0:52:34	NPK 13:0:45	Ammonium Sulphate	Magnesium Sulphate
After transplanting	0 – 30	1.5	1.5	2.5	--	2	-	2
Flowering/ Fruit Setting	31 – 65	2	2	5	--	4	2	4
First Harvest	66 – 95	2	--	5	2	4	2	4
Upto end of Harvest	96 – 300	2	--	5	2	4	1.5	4

Note :

- Foliar Spray of Micronutrients like Mn Sulphate @ 2 gm per litre and Boron @ 1 gm per litre once in a week.
- Once in a week give plain Irrigation.

### 3.4 Observations Recorded

The observations on the following growth and development parameters, earliness, fruit yield and fruit quality characteristics were recorded from each replication during entire period of experiment on the following parameters for two continuous seasons and the data was pooled:

1. **Plant height (cm)** : Plant height was recorded from ten randomly selected plants from each replication at final harvest. Plant height from the ground level to the tip of the plant was measured in centimeter and averaged.
2. **Number of branches per plant** : Plants were pruned after one month of transplanting and two braches per plant were retained for longer fruiting span.
3. **First flower initiation (Days)** : Observation was recorded for the number of days taken to open the first flower from the date of sowing.
4. **First fruit harvest (Days)** : Observation was recorded for the number of days taken to harvest the first fruit from the date of sowing.
5. **Number of fruits per plant** : Total number of fruits from different pickings from ten selected plants for each replication during the cropping season was added and average was made for fruits per plant.
6. **Percent fruit set (%)** : Observation was recorded by tagging flowers at the time of anthesis of selected plants at weekly intervals and the fruits with tags were counted to work out percentage.
7. **Fruit length (cm)** : Length of ten randomly selected mature fruits at marketable stage was measured in centimetre using vernier calliper and average was worked out.
8. **Fruit diameter (cm)** : Ten mature fruits at marketable stage were used to measure the diameter of fruit in centimetres using Vernier Calipers at the widest point of the fruit and average was computed.
9. **Individual fruit weight (gm)** : Fresh weight of ten randomly selected mature fruits at marketable stage was recorded in grams using electronic balance and the average was calculated.

10. **Fruit volume (cc) :** Fruit volume was recorded from ten randomly selected individual fruits by water displacement method in a jar containing water and the displaced water was measured by using measuring cylinder.
11. **Fruit rind thickness (cm):** Thickness of rind of ten randomly selected fruits for each replication was measured using Vernier Calliper.
12. **Shelf life (Days):** Ten randomly selected mature fruits were kept at ordinary room temperature with shrink wrapping immediately after harvest and the days for which the fruit remained consumable were calculated.
13. **Total fruit yield per plant (kg):** Fruits harvested from ten randomly selected plants at each harvest were weighed using electronic balance and the data was recorded and summarized to work out total fruit yield.
14. **Total fruit yield per square metre (kg):** Total number of plants ( $n$ ) was calculated in 1 m<sup>2</sup> cropping area and total yield was worked out as ( $n * x$ ) on the basis of total fruit yield per plants ( $x$ ).
15. **Total fruit yield per hectare (Tonnes):** Fruit yield per square metre was used to calculate fruit yield per hectare as area of 1 Hectare = 10000 m<sup>2</sup>.
16. **Tolerance to major pests:** Infestation of major pests, i.e., thrips and mites on plants was recorded on the visual basis and resistance of different hybrid genotypes to pest was worked out using rating scale 0 (Highly resistance) to 10 (Highly susceptible).
17. **Temperature (°c):** Temperature at weekly intervals was recorded to know the optimum temperature range for getting higher yield.
18. **Relative humidity (%):** RH at weekly intervals was recorded to know the optimum RH range for getting higher yield.
19. **Light intensity (klux):** It was measured with Klux metre.

### 3.5 Economics

Economics of sweet pepper production under different protected structures was worked out by considering the market price of inputs and produce. The following formula was used to calculate the benefit : cost ratio:-

$$\text{Net returns (Rs/500 m}^2\text{)} = \text{Gross returns (Rs/500 m}^2\text{)} - \text{cost of cultivation (Rs/500 m}^2\text{)}$$

$$\text{Benefit: Cost (B:C) Ratio} = \frac{\text{Gross returns (Rs/500 m}^2\text{)}}{\text{Cost of cultivation (Rs/500 m}^2\text{)}}$$

### 3.6 Statistical analysis

The data so recorded were analyzed as per method suggested by Steel and Torrie (1981). For this data were recorded for all the observations under study as per the data collection methods (heading 3.4) for both the cropping season of 2014-15 and 2015-16 separately for the three replications from each main plot (protected structures). The replication wise data were pooled over the two seasons and subjected to the pooled analysis of variance for the design using computer programme CPCS1 (Cheema and Singh 1990) to obtain estimate of experimental error mean squares, which was used for further analysis.

It involved modeling the data using the linear model shown below:

$$\text{Model: } Y_{ijk} = \mu + \rho_i + \tau_j + \delta_{ij} + \beta_k + (\tau\beta)_{jk} + \epsilon_{ijk}$$

Such that:

$Y_{ijk}$  = observation corresponding to  $k^{\text{th}}$  level of sub-plot factor (B),  $j^{\text{th}}$  level of main plot factor (A) and the  $i^{\text{th}}$  replication.

$\mu$  = general mean

$\rho_i$  =  $i^{\text{th}}$  block effect

$\tau_j$  =  $j^{\text{th}}$  block effect

$\beta_k$  =  $k^{\text{th}}$  main plot treatment effect

$(\tau\beta)_{jk}$  = interaction between  $j^{\text{th}}$  level of main-plot treatment and the  $k^{\text{th}}$  level of sub-plot treatment.

$\epsilon_{ijk}$  = experimental error

The error components  $\delta_{ij}$  and  $\epsilon_{ijk}$  are independently and normally distributed with means zero and respective variances  $\sigma^2_{\delta}$  and  $\sigma^2_{\epsilon}$ .



### Analysis of variance

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
<i>Whole plot analysis</i>				
Replication	r-1	ssR	-	-
Main plot treatment (A)	a-1	ssA	MsA	msA/msE <sub>1</sub>
Main plot error (E <sub>1</sub> )	(r-1)(a-1)	ssE <sub>1</sub>	msE <sub>1</sub> =E <sub>a</sub>	
<i>Sub-plot analysis</i>				
Sub-plot treatment (B)	b-1	ssB	MsB	msB/msE <sub>2</sub>
Interaction (AxB)	(a-1)(b-1)	ss(AB)	ms(AB)	ms(AB)/msE <sub>2</sub>
Sub-plot error (E <sub>2</sub> )	a(r-1)(b-1)	ssE <sub>2</sub>	msE <sub>2</sub> =E <sub>b</sub>	
Total	rab-1	Sstot		

Where:

ssR = Sum of squares due to replication

ssA= Sum of squares due to main plot

MsA= Mean squares due to main plot

msE<sub>1</sub> = Mean squares due to main plot error

ssB= Sum of squares due to sub-plots

MsB = Mean squares due to sub-plots

ms(AB) = Mean squares due to interaction

msE<sub>2</sub> = Mean squares due to sub-plot interaction error

The mean square due to replication, main plot and interaction were tested against error variance by 'F' test at 5 percent levels of significance.

### **3.7 Different Protected Structures and Fruits of Capsicum hybrids**

#### **(a) Structures used for experimental work**

##### **1. Hi-Tech Poly House (Fan & Pad System)**



##### **2. Naturally Ventilated Polyhouse (NVPH)**



### 3. Walk-in-Tunnel (WIT)



### 4. Net House (NH)



**(b) Fruits of different Capsicum hybrids**

**(1) Green group hybrids**

**Pasrella**



**Indra**

**Starlet**



**(2) Red group hybrids**

**Bomby**



**Inspiration**

**Mazillia**



**(3) Yellow group hybrids**

**Orobelle**



**Bachata**

**Sven**



## CHAPTER – IV

### RESULT AND DISCUSSION

The present investigation entitled, ‘Performance of Sweet pepper (*Capsicum annuum* L.) cultivars and economics under protected structures in Punjab’ was carried out to evaluate the influence of different protected structures, i.e., naturally ventilated polyhouse, nethouse, walk-in-tunnel on crop maturity, productivity, prolonged fruiting span and enhanced shelf life of different coloured capsicum hybrids. The experimental results obtained from the present studies have been discussed in this chapter for different plant characteristics and are presented as under.

#### **4.1 Plant height (cm)**

Among the green group hybrids, the plant height was significantly influenced by the growing structures and the interaction effects were also significant (Table 4.1). The plants in NVPH had recorded highest mean plant height (124.52 cm) followed by walk-in-tunnel (120.88 cm) and nethouse (112.61 cm). The hybrid Starlet attained maximum plant height (126.76 cm) closely followed by Indra (124.96 cm) under NVPH and Pasrella had minimum plant height (108 cm) under nethouse. Overall the hybrid Starlet showed maximum mean plant height (122.77 cm) as compared to other hybrids under the NVPH, nethouse and walk-in-tunnel structures (Table 4.4a).

Among the red group hybrids, the different growing structures had significant influence on plant height and different hybrids had significant differences for the mean plant height and interaction effects (Table 4.2). The highest mean plant height (103.74 cm) was observed under NVPH structures followed by walk-in-tunnel (101.42 cm) and nethouse (97.51 cm). The hybrid Bomby attained maximum plant height (109.83 cm) under the NVPH structure and hybrid Mazillia had minimum plant height (92.63 cm) under nethouse. Overall the hybrid Bomby recorded maximum mean plant height (106.80 cm) followed by Inspiration (100.58 cm) under the NVPH, nethouse and walk-in-tunnel structures (Table 4.4b).

Among the yellow group hybrids, the mean plant height was significantly influenced by the growing structures (Table 4.3), and significant mean differences and interaction effects were also recorded among the different hybrids for plant height. Walk-in-tunnel structure had recorded maximum mean plant height (106.31 cm),

**Table 4.1: Analysis of variance for influence of different protected structures among green coloured capsicum hybrids.**

<b>Name of character</b>	<b>Protected Structure (A)</b>	<b>Variety (B)</b>	<b>Interaction (A x B)</b>
Plant Height (cm)	335.39*	137.50*	4.91*
First flower initiation (days)	21.58*	15.63*	0.33*
First fruit harvest (days)	380.08*	84.58*	3.19*
Number of fruits per plant	57.92*	26.23*	2.37*
Percent fruit set (%)	38.01*	57.83*	0.44
Fruit length (cm)	0.97*	3.92*	0.30*
Fruit diameter (cm)	3.02*	1.21*	0.91*
Individual fruit weight (g)	153.43*	119.12*	6.75*
Fruit volume (cc)	354.58*	531.25*	7.70*
Rind thickness (cm)	0.28*	0.33*	0.45*
Shelf life (days)	5.06*	3.40*	0.02
Total yield per plant (kg)	2.21*	0.41*	0.19*
Total yield per square metre (kg)	19.96*	3.72*	0.17*
Total yield per hectare (tonnes)	1996.85*	372.93*	17.20*
Infestation of major pests (%)	2.44*	0.16*	0.23*

**\*Significant at 0.05 percent level**



**Table 4.2: Analysis of variance for influence of different protected structures among red coloured capsicum hybrids.**

<b>Name of character</b>	<b>Protected Structure (A)</b>	<b>Variety (B)</b>	<b>Interaction (A x B)</b>
Plant Height (cm)	89.30*	298.74*	6.55*
First flower initiation (days)	49.83*	96.97*	4.84*
First fruit harvest (days)	67.05*	91.20*	0.69*
Number of fruits per plant	9.55*	2.90*	0.95
Percent fruit set (%)	38.25*	7.76*	0.31
Fruit length (cm)	0.26*	0.72*	0.11*
Fruit diameter (cm)	3.03*	1.22*	0.45*
Individual fruit weight (g)	137.86*	386.97*	48.73*
Fruit volume (cc)	693.66*	1244.77*	204.52*
Rind thickness (cm)	0.35*	0.95*	0.31*
Shelf life (days)	5.13*	0.72*	0.08*
Total yield per plant (kg)	0.66*	0.48*	0.54*
Total yield per square metre (kg)	6.02*	4.34*	0.49*
Total yield per hectare (tonnes)	602.51*	434.77*	4.93*
Infestation of major pests (%)	2.46*	0.16*	0.36

**\*Significant at 0.05 percent level**

**Table 4.3: Analysis of variance for influence of different protected structures among yellow coloured capsicum hybrids.**

<b>Name of character</b>	<b>Protected Structure (A)</b>	<b>Variety (B)</b>	<b>Interaction (A x B)</b>
Plant Height (cm)	292.61*	63.36*	25.94*
First flower initiation (days)	2.03*	19.55*	0.96*
First fruit harvest (days)	130.53*	57.61*	2.89*
Number of fruits per plant	11.20*	6.34*	0.47*
Percent fruit set (%)	29.15*	18.07*	1.04*
Fruit length (cm)	1.68*	2.94*	0.36*
Fruit diameter (cm)	0.63*	0.61*	0.11
Individual fruit weight (g)	21.94*	2675.16*	7.94*
Fruit volume (cc)	190.06*	12770.85*	15.68*
Rind thickness (cm)	0.76*	0.12*	0.37*
Shelf life (days)	2.75*	0.69*	0.002
Total yield per plant (kg)	0.48*	0.80*	0.21*
Total yield per square metre (kg)	4.40*	7.24*	0.19*
Total yield per hectare (tonnes)	440.01*	724.00*	19.03*
Infestation of major pests	1.73*	0.54*	0.88

**\*Significant at 0.05 percent level**

**Table 4.4: Plant height (cm) of capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	124.96	113.43	122.06	120.15
	Pasrella	121.83	108.00	115.43	115.08
	Starlet	126.76	116.40	125.16	122.77
Mean A		124.52	112.61	120.88	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	1.54	0.90		1.57	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	109.83	102.26	108.30	106.80
	Inspiration	104.56	97.63	99.56	100.58
	Mazillia	96.83	92.63	96.40	95.28
Mean A		103.74	97.51	101.42	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.71	0.73		1.27	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	103.26	93.83	101.80	99.63
	Bachata	104.60	96.40	113.06	104.68
	Sven	102.50	95.73	104.06	100.76
Mean A		103.45	95.32	106.31	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	2.31	1.93		3.35	

CD at P=0.05

followed by NVPH (103.45 cm) and nethouse (95.32 cm). Hybrid Bachata attained maximum plant height (113.06 cm) under walk-in-tunnel and Orobelle had minimum plant height (93.83 cm) under nethouse cultivation (Table 4.4c). Similarly, the Bachata had maximum average plant height (104.68 cm) followed by Sven (100.76) in the NVPH, nethouse and walk-in-tunnel structures. The favorable environmental conditions in polyhouse seems to have stimulated cell division and cell enlargement in the growing apex of plant which resulted in attaining maximum plant height and pruning of axillary shoots at their emergence have improved the plant height. Similar findings have also been recorded by Singh *et al* (2005).

#### **4.2 Number of branches per plant**

Capsicum plant has multiple branching habits. Thus, the fruit development may be controlled by maintaining the branching pattern from 1 to 4 branches per plant for prolonged fruiting span. Previous studies also concluded that pruning methods varied under different plant densities (Dasgan and Abak, 2003; Maniutiu *et al.* 2010). Shaw and Cantliffe (2002), and Maniutiu *et al.* (2010) observed that due to the heavy vegetative growth and fruit load on the coloured pepper plants shoot pruning is an important factor. The plants were pruned after one month of transplanting and two braches per plant were retained to grow plants upright for the better penetration of light and air in all the green, red, and yellow colour group hybrids. It improved the fruit setting, and contributed to the high yield due to large sized fruits for longer fruiting span. Pant *et al* (2005) observed that trained plant enjoyed better aeration and environment in greenhouse which result in full utilization of nutrients under favourable ambient climatic conditions. Similar finding of pruning system on the upright behaviour of growth for better light penetration, yield and quality traits like improved fruit set, early fruit ripening, high yield and large sized fruit of green-house grown capsicum was reported by Jovicich *et al.* (2004), and Zende (2008). It has been observed in present study that pruning is effective in improving air circulation which reduces relative humidity percentage and limits the spread of diseases. Similar practice for pruning of branches was also followed by Esiyok *et al* (1994) to maintain proper balance between fruit number and fruit size. Lone (2014) have also registered that two shoots per plant recorded significantly higher fruit length (8.3 cm), fruit

**Table 4.5: First flower initiation (days) of capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	42.43	45.26	41.93	43.21
	Pasrella	44.30	46.93	43.80	45.01
	Starlet	45.33	47.10	44.90	45.77
Mean A		44.02	46.43	43.54	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.20	0.31		0.55	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	50.40	48.26	46.09	48.25
	Inspiration	45.46	48.03	42.33	45.27
	Mazillia	52.76	53.90	48.83	51.83
Mean A		49.54	50.06	45.75	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.48	0.49		0.85	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	46.56	47.70	46.16	46.81
	Bachata	44.93	46.40	45.06	45.46
	Sven	48.43	48.23	48.56	48.41
Mean A		46.64	47.44	46.60	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.52	0.49		0.85	

CD at P=0.05

breadth (7.7 cm), average fruit weight (92.4 g), pericarp thickness (0.79 cm), and longer shelf life (8.5 days).

### **4.3 First flower initiation (days)**

Among the green group the days taken for first flower initiation was significantly influenced by the different growing structures and the significant mean differences and interaction effects were observed for different hybrids under experiment (Table 4.1). The walk-in-tunnel structure had high influence on the earliness of hybrids as it had minimum days taken to first flower initiation (43.54) as compared to NVPH (44.02) and nethouse (46.43). Indra recorded minimum days taken to first flower initiation (41.93) under walk-in-tunnel and Starlet (47.10) had maximum days taken to first flower initiation under the nethouse. Overall the Indra recorded minimum mean first flower initiation at 43.21 days followed by Pasrella (45.01) and Starlet (45.77) under three different growing structures (Table 4.5a).

Among the red group hybrids three different growing structures had recorded significant influence on the first flower initiation (days) and also the different hybrids had significant mean difference and interaction effect for the days taken to first flower initiation (Table 4.2). Walk-in-tunnel had recorded minimum mean days taken to first flower initiation (45.75) followed by NVPH (49.54) and nethouse (50.06). Under walk-in-tunnel, Inspiration had earliest first flower initiation at 42.33 days and Mazillia had late flowering (53.90) under nethouse. Overall Inspiration (45.27) had mean early first flower initiation followed by Bomby (48.25) under NVPH, nethouse and walk-in-tunnel structures (Table 4.5b).

Among the yellow group the days taken for first flower initiation was significantly influenced by the different growing structures and also the significant mean differences and interaction effects were observed for different hybrids under study (Table 4.3). Walk-in-tunnel structure had high influence on minimum mean days taken to first flower initiation (46.60), which was at par with the NVPH (46.64) followed by nethouse (47.44). Bachata recorded minimum days taken to first flower initiation (44.93) under NVPH and Sven had maximum days taken to first flower initiation (48.56) under the walk-in-tunnel. Overall the Bachata recorded mean first flower initiation at 45.46 days followed by Orobelle (46.81) and Sven (48.41) under

three different growing structures, i.e., NVPH, nethouse and walk-in-tunnel (Table 4.5c).

Occurrence of early flowering is basically a genetic character of each hybrid. However, favourable temperature regime in protected conditions for longer period showed great impact on the genetic constitution of plant to express its full genetic potential. Better environmental conditions and available nutrients seems to have brought quick changes in plant growth and development. It might have triggered the hormonal action due to ambient environment favouring flower forming hormone the present findings are in line with the results obtained by Nagalakshmi *et al* (2001) and Meenakshi and Vadivel (2005).

#### **4.4 First fruit harvest (Days)**

Three growing structures namely NVPH, nethouse and walk-in-tunnel had significant differences for the first fruit harvest (days) among green group capsicum hybrids and also different hybrids had significant mean differences and interaction effects for this character (Table 4.1). Growing structure NVPH had recorded significant early first fruit harvest (83.34 days) as compared to walk-in-tunnel (87.97) and nethouse (96.17). Under NVPH Pasrella had early first fruit harvest (79.46 days) and Starlet had late first fruit harvest (98.23) under nethouse conditions. Overall the Pasrella had taken minimum number of days to first fruit harvest (85.83) followed by India (89.80) and Starlet (91.86) under the different growing structures (Table 4.7a).

Among the red group capsicum hybrids the different growing structures had significant influence on the first fruit harvest (days) and also there was significant mean differences and interaction effects were recorded among different hybrids (Table 4.2). Walk-in-tunnel recorded early first fruit harvest (109.20) followed by NVPH (111.36) and nethouse (114.62). Inspiration recorded minimum days taken to first fruit harvest (105.83) under walk-in-tunnel and Mazillia had maximum days taken to first fruit harvest (117.56) under nethouse. Overall the hybrid Inspiration had the early first fruit harvest at 108.44 days followed by Bomby (111.94) and Mazillia (114.80) (Table 4.7b).

Among the yellow group, the first fruit harvest (days) was significantly influenced by the different growing structures NVPH, nethouse and walk-in-tunnel; and the

**Table 4.6: First fruit harvest (days) of capsicum hybrids influenced by different protected structures.**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	83.76	97.86	87.76	89.80
	Pasrella	79.46	92.43	85.60	85.83
	Starlet	86.80	98.23	90.56	91.86
Mean A		83.34	96.17	87.97	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.44	0.44		0.77	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	112.06	114.80	108.96	111.94
	Inspiration	108.00	111.50	105.83	108.44
	Mazillia	114.03	117.56	112.80	114.80
Mean A		111.36	114.62	109.20	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.77	0.39		0.69	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	99.46	107.93	99.96	102.45
	Bachata	99.63	104.93	98.19	100.92
	Sven	103.86	109.56	104.16	105.86
Mean A		100.98	107.47	100.77	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	1.16	0.73		1.27	

CD at P=0.05



significant mean differences and interaction effects were observed among different hybrids for these observations under experiment (Table 4.3). Walk-in-tunnels structure had high influence on minimum mean days taken to first fruit harvest (100.77) which was at par with the NVPH (100.98) significantly followed by nethouse (107.47). Bachata recorded minimum number of days taken to first fruit harvest (98.19) in walk-in-tunnel and Sven had maximum number of days taken to first fruit harvest (109.56) in nethouse. Overall the Bachata recorded significant mean early first fruit harvest (100.92) followed by Orobelle (102.45) and Sven (105.86) under NVPH, nethouse and walk-in-tunnel structures (Table 4.6c).

#### **4.5 Percent fruit set (%)**

Among the green group hybrids the different growing structures had significant influence on the percent fruit set, and also significant mean differences and non-significant interaction effects among hybrids were recorded (Table 4.1). The highest mean percent fruit set (44.15) was recorded in NVPH which was significant. It followed by walk-in-tunnel (41.66) and nethouse (40.07). Indra gained maximum percent fruit set (46.23) in NVPH. Overall maximum mean percent fruit set (44.17) was recorded by Indra followed by Pasrella (42.52) and Starlet (39.20) in different protected structures (Table 4.7a).

The different growing structures had significant influence on the percent fruit set. Among the red group hybrids, and significant mean differences and non-significant interaction effects among hybrids were also recorded for this parameter (Table 4.2). Maximum mean percent fruit set (41.13) was recorded in NVPH significantly followed by walk-in-tunnel (38.30) and nethouse (37.12). Inspiration had maximum percent fruit set (42.43) in NVPH structure. Overall the Inspiration recorded maximum mean percent fruit set (39.85) followed by Bomby (38.67) and Mazillia (38.02) in different growing structures (Table 4.7b).

Among the yellow group capsicum hybrids, NVPH, nethouse and walk-in-tunnel had significant influence on the percent fruit set, and their significant mean differences and interaction effects were also recorded for different hybrids under study (Table 4.3). NVPH recorded significantly highest percent fruit set (40.26)

**Table 4.7: Percent fruit set (%) of capsicum hybrids influenced by different protected structures.**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	46.23	42.63	43.66	44.17
	Pasrella	44.46	40.70	42.40	42.52
	Starlet	41.76	36.90	38.93	39.20
Mean A		44.15	40.07	41.66	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.39	0.40		NS	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	40.86	36.76	38.40	38.67
	Inspiration	42.43	37.96	39.16	39.85
	Mazillia	40.10	36.63	37.33	38.02
Mean A		41.13	37.12	38.30	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.28	0.45		NS	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	40.80	36.20	38.26	38.42
	Bachata	41.83	38.00	39.93	39.92
	Sven	38.16	35.80	37.30	37.08
Mean A		40.26	36.66	38.50	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.26	0.30		0.53	

CD at P=0.05

followed by walk-in-tunnel (38.50) and nethouse (36.66). Bachata recorded maximum percent fruit set (41.83) in NVPH and Sven recorded minimum percent fruit set (35.80) in nethouse. Overall Bachata had mean higher percent fruit set (39.92) followed by Orobelle (38.42) and Sven (37.08) under different protected structures (Table 4.7c). The significant difference in the ability of plant to set fruit depends upon the pollination, quick pollen germination, stigma receptivity, effective pollen tube growth in style and fertilization in the ovary of flower. Similar results for higher percent fruit set were also recorded by Kurubetta and Patil (2009) under NVPH.

#### **4.6 Number of fruits per plant**

Significant influence of growing structures namely NVPH, nethouse and walk-in-tunnel was recorded on green coloured capsicum hybrids, and significant mean differences and their interaction effects for the number of fruits per plants were also recorded (Table 4.1). Among the different growing protected structures, the NVPH had recorded maximum significant mean number of fruits per plant (19.10) as compared to walk-in-tunnel (16.96) and nethouse (14.05). Indra had maximum number of fruits per plant (21.49) in NVPH and Starlet had minimum number of fruits per plant (12.93) in nethouse. Overall the higher mean number of fruits per plant recorded by Indra (18.56) which was significant. It was followed by Pasrella (16.34) and Starlet (15.20) (Table 4.8a).

Among the red group capsicum hybrids, the different growing structures had significant influence on the mean number of fruit per plant. Significant mean differences and non-significant interaction effects among hybrids were also recorded for this character (Table 4.2). The average number of fruits per plant in NVPH (12.54) was significantly higher as compared to walk-in-tunnels (11.53) and nethouse (10.48). Inspiration recorded maximum number of fruits per plant (13.19) in NVPH. Overall the maximum average number of fruits per plant was recorded from Inspiration (12.01) which was significant. It was followed by Mazillia (11.65) and Bomby (10.90) in different protected structures (Table 4.8b).

Among the yellow group capsicum hybrids, the growing structures NVPH, nethouse and walk-in-tunnel had significant influence on the number of fruits per plant and significant mean differences and their interaction effects were also recorded

**Table 4.8: Number of fruits per plant of capsicum hybrids influenced by different protected structures.**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	21.49	15.97	18.22	18.56
	Pasrella	19.33	13.24	16.46	16.34
	Starlet	16.48	12.93	16.20	15.20
Mean A		19.10	14.05	16.96	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.52	0.83		1.45	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	11.97	9.76	10.96	10.90
	Inspiration	13.19	10.88	11.96	12.01
	Mazillia	12.48	10.81	11.66	11.65
Mean A		12.54	10.48	11.53	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.19	0.21		NS	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	14.23	12.10	13.04	13.12
	Bachata	15.77	13.12	14.83	14.57
	Sven	15.80	13.91	14.04	14.58
Mean A		15.26	13.04	13.97	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.27	0.24		0.42	

CD at P=0.05

significant for different hybrids under study (Table 4.3). NVPH recorded significantly maximum mean number of fruits per plants (15.26) and was followed by walk-in-tunnel (13.97) and nethouse (13.04). Sven had maximum number of fruits per plant (15.80) which was at par with Bachata (15.77) in NVPH and Orobelle recorded minimum number of fruits per plant (12.10) in nethouse conditions. Overall Sven had maximum number of fruits per plant (14.58) which was at par with Bachata (14.57) and significantly followed by Orobelle (13.12) (Table 4.8c). Similar findings were also reported by Megaraja (2000), Naik (2005), and Singh *et al* (2011), for the maximum number of fruits per plant in polyhouse.

#### **4.7 Individual fruit weight (g)**

Among the green group hybrids, the different growing structures had significant influence on the individual fruit weight (g) and also significant mean differences and their interaction effects was significant among hybrids (Table 4.1). Maximum mean individual fruit weight (176.41 g) was recorded in NVPH followed by walk-in-tunnel (174.10 g) and nethouse (168.38 g) for different hybrids. Starlet recorded maximum individual fruit weight (179.06 g) which was at par with Pasrella (178.96 g) in NVPH structure, and Indra had minimum individual fruit weight (165.43 g) in nethouse. Overall Starlet recorded maximum mean individual fruit weight (175.81 g) followed by Pasrella (174.22 g) and Indra (168.86 g) in different protected structures (Table 4.9a).

Among the red group hybrids, the different growing structures had significant influence on individual fruit weight. Significant mean differences and interaction effect among hybrids were also recorded significant for this character (Table 4.2). Maximum mean individual fruit weight (208.78 g) was recorded in NVPH followed by walk-in-tunnel (204.33 g) and nethouse (200.98 g) for different hybrids. Inspiration recorded maximum individual fruit weight (216.53 g) in NVPH which was at par with the same hybrid (214.00 g) in walk-in-tunnel. Minimum individual fruit weight was recorded by Bomby (194.33 g) in walk-in-tunnel structure. Overall the maximum mean individual fruit weight was recorded by Inspiration (211.34 g) which was significantly followed by Mazillia (204.53 g) and Bomby (198.23 g) in different protected structures (Table 4.9b).

**Table 4.9: Individual fruit weight (gm) of capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	171.20	165.43	169.96	168.86
	Pasrella	178.96	167.76	175.93	174.22
	Starlet	179.06	171.96	176.40	175.81
Mean A		176.41	168.38	174.10	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	1.62	1.16		2.02	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	201.06	199.30	194.33	198.23
	Inspiration	216.53	203.50	214.00	211.34
	Mazillia	208.76	200.16	204.66	204.53
Mean A		208.78	200.98	204.33	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	2.04	1.86		3.23	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	183.01	179.93	183.26	182.07
	Bachata	190.73	187.06	186.16	187.98
	Sven	156.10	153.60	157.13	155.61
Mean A		176.61	173.53	175.52	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.95	0.95		1.66	

CD at P=0.05

Among the yellow group hybrids, the individual fruit weight was significantly influenced by different growing structures and also the significant mean differences and their interaction effects were observed significant among different hybrids under study (Table 4.3). NVPH recorded maximum mean individual fruit weight (176.61 g) followed by walk-in-tunnel (175.52 g) and nethouse (173.53 g) for different hybrids. Bachata recorded maximum individual fruit weight (190.73 g) in NVPH and Sven recorded minimum individual fruit weight (153.60 g) in the nethouse structure. Overall Bachata recorded significant maximum mean individual fruit weight (187.98 g) followed by Orobelle (182.07 g) and Sven (155.61 g) in NVPH, nethouse and walk-in-tunnel structures (Table 4.9c). These findings for maximum individual fruit weight under polyhouse are in line with the results reported by Naik (2005), Singh *et al* (2007), Kurubetta and Patil (2009), and Halim and Islam (2013).

#### **4.8 Fruit length (cm)**

The different protected structures had significant influence on the mean fruit length among the green group hybrids and also significant mean differences and their interaction effects among hybrids were recorded significant for this character (Table 4.1). Walk-in-tunnel had the maximum mean fruit length (9.36 cm) which was significant. It was followed by nethouse (8.93 cm) and NVPH (8.72 cm) for different hybrids. Pasrella had the maximum fruit length (9.63 cm) in walk-in-tunnel and Starlet had minimum fruit length (7.60 cm) in NVPH. Under the different protected structures overall maximum mean fruit length (9.38 cm) was recorded in both the hybrids Indra and Pasrella which was followed by Starlet (8.24 cm) (Table 4.10a).

Among the red group hybrids, the different growing structures had significant influence on the fruit length. Significant mean differences and their interaction effect among hybrids were also recorded for this character (Table 4.2). Walk-in-tunnel recorded maximum mean fruit length (9.28 cm) followed by NVPH (9.04 cm) and nethouse (8.95 cm) for different hybrids. Inspiration recorded maximum fruit length (9.70 cm) in walk-in-tunnel and Bomby recorded minimum fruit length (8.60 cm) in NVPH structure. Overall the maximum mean fruit length was recorded from Inspiration (9.36 cm) followed by Mazillia (9.12 cm) and Bomby (8.80 cm) in different protected structures (Table 4.10b).

**Table 4.10: Fruit length (cm) of capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	9.10	9.36	9.7	9.38
	Pasrella	9.46	9.06	9.63	9.38
	Starlet	7.60	8.36	8.76	8.24
Mean A		8.72	8.93	9.36	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.13	0.14		0.24	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	8.60	8.83	8.96	8.80
	Inspiration	9.40	9.00	9.70	9.36
	Mazillia	9.13	9.03	9.20	9.12
Mean A		9.04	8.95	9.28	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.13	0.11		0.20	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	8.00	8.16	8.83	8.33
	Bachata	8.29	9.03	9.76	9.03
	Sven	7.96	7.60	8.13	7.90
Mean A		8.08	8.26	8.91	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.24	0.11		0.19	

CD at P=0.05



**Table 4.11: Fruit diameter (cm) of capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	6.76	6.43	7.50	6.90
	Pasrella	6.00	5.50	7.00	6.16
	Starlet	6.56	6.16	7.03	6.58
Mean A		6.44	6.03	7.17	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.18	0.12		0.22	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	7.43	6.96	7.96	7.45
	Inspiration	7.30	6.93	8.23	7.48
	Mazillia	6.60	6.40	7.50	6.83
Mean A		7.11	6.76	7.90	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.21	0.06		0.10	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	7.33	6.96	7.50	7.26
	Bachata	7.30	7.03	7.63	7.32
	Sven	6.80	6.63	7.10	6.84
Mean A		7.14	6.87	7.41	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.08	0.09		NS	

CD at P=0.05

Among the yellow group capsicum hybrids, the different growing structures had significant influence on the fruit length. Significant mean differences and their interaction effect among hybrids were also recorded significant for this character (Table 4.3). Walk-in-tunnel recorded maximum mean fruit length (8.91 cm) followed by nethouse (8.26 cm) and NVPH (8.08 cm) for different hybrids. Bachata had maximum fruit length (9.76 cm) in walk-in-tunnel and Sven had minimum fruit length (7.60 cm) in nethouse. Overall the maximum mean fruit length was recorded from Bachata (9.03 cm) followed by Orobelle (8.33 cm) and Sven (7.90 cm) in different protected structures (Table 4.10c). Similarly, highest fruit length (5.98 cm) was recorded by Farooq *et al* (2015) under plastic tunnel. However, maximum fruit length under polyhouse (8.49 cm) was reported by Naik (2005).

#### **4.9 Fruit diameter (cm)**

There was a significant difference among growing structures namely NVPH, nethouse and walk-in-tunnel recorded in green coloured hybrids. Different hybrids under study had significant mean differences and significant interaction effects for the fruit diameter (Table 4.1). Among the different protected structures the maximum mean fruit diameter was recorded in walk-in-tunnel (7.17 cm) followed by NVPH (6.44 cm) and nethouse (6.03 cm) for different hybrids. Indra had maximum fruit diameter (7.50 cm) in walk-in-tunnel and Pasrella had minimum fruit diameter (5.50 cm) in nethouse. Overall the mean fruit diameter recorded from Indra (6.90 cm) which was maximum as compared to Starlet (6.58 cm) and Pasrella (6.16 cm) in different protected structures (Table 4.11a).

Among the red group capsicum hybrids, the different growing structures had significant influence on the mean fruit diameter. Significant mean differences and their interaction effect among hybrids were also recorded significant (Table 4.2). Walk-in-tunnel recorded maximum mean fruit diameter (7.90 cm) followed by NVPH (7.11 cm) and nethouse (6.76 cm) for different hybrids. Inspiration had maximum fruit diameter (8.23 cm) in walk-in-tunnel and Mazillia had minimum fruit diameter (6.40 cm) in nethouse conditions. Overall the maximum mean fruit diameter recorded from Inspiration (7.48 cm) which was at par with Bomby (7.45 cm), followed by Mazillia (6.83 cm) in various protected structures (Table 4.11b).

Among the yellow group capsicum hybrids, the growing structures NVPH, nethouse and walk-in-tunnel had significant influence on the fruit diameter, and significant mean differences and non-significant interaction effects were recorded for different hybrids under study (Table 4.3). Walk-in-tunnel recorded maximum mean fruit diameter (7.41 cm) which was significantly followed by NVPH (7.14 cm) and nethouse (6.87 cm) for different hybrids. Bachata had maximum fruit diameter (7.63 cm) in walk-in-tunnel. Overall Bachata had maximum mean fruit diameter (7.32 cm) which was at par with Orobelle (7.26 cm), and it was significantly followed by Sven (6.84 cm) under different growing structures (Table 4.11c). Similar result for maximum fruit diameter under plastic tunnel have also been observed by Farooq *et al* (2015).

#### **4.10 Fruit volume (cc)**

Three different growing structures had significant influence on the fruit volume among green group capsicum hybrids and also different hybrids had significant mean differences and interaction effects were also significant for this character (Table 4.1). NVPH had recorded maximum fruit volume (358.44 cc) followed by walk-in-tunnel (352.33 cc) and nethouse (345.88 cc) for different hybrids. Pasrella had highest fruit volume (363.66 cc) in NVPH and Indra had minimum fruit volume (337.00 cc) in nethouse conditions. Overall Pasrella had maximum mean fruit volume (359.22 cc) followed by Starlet (353.44 cc) and India (344.00 cc) in the different protected structures (Table 4.12a).

Among the red group capsicum hybrids the different growing structures had significant influence on the fruit volume and there were significant mean differences and their interaction effects were also recorded significant among different hybrids (Table 4.2). NVPH recorded maximum means fruit volume (417.33 cc) followed by walk-in-tunnel (408.33 cc) and nethouse (399.77 cc). Inspiration recorded maximum fruit volume (434.00 cc) in NVPH and Bomby recorded minimum fruit volume (393.33 cc) in walk-in-tunnel. Overall Inspiration had maximum means fruit volume (421.77 cc) followed by Mazillia (404.22 cc) and Bomby (399.44 cc) in different growing structures (Table 4.12b).

**Table 4.12: Fruit volume (cc) of capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	350.66	337.00	344.33	344.00
	Pasrella	363.66	353.33	360.66	359.22
	Starlet	361.00	347.33	352.00	353.44
Mean A		358.44	345.88	352.33	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	2.01	1.30		2.25	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	407.33	397.66	393.33	399.44
	Inspiration	434.00	402.66	428.66	421.77
	Mazillia	410.66	399.00	403.00	404.22
Mean A		417.33	399.77	408.33	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	2.10	2.61		4.52	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	362.66	355.33	358.00	358.66
	Bachata	388.66	379.33	376.00	381.33
	Sven	312.33	304.33	306.66	307.77
Mean A		354.55	346.33	346.88	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	3.15	2.18		3.78	

CD at P=0.05

Among the yellow group capsicum hybrids the fruit volume was significantly influenced by different growing structures namely NVPH, nethouse and walk-in-tunnel. The significant mean differences and their interaction effects were also significantly observed among different hybrids (Table 4.3). NVPH had significant influence on mean fruit volume (354.55 cc) followed by walk-in-tunnel (346.88 cc) which was at par with the nethouse (346.33 cc). Bachata recorded maximum fruit volume (388.66 cc) in NVPH and Sven recorded minimum fruit volume (304.33 cc) when grown in walk-in-tunnel. Overall Bachata recorded significant maximum mean fruit volume (381.33 cc) followed by Orobelle (358.66 cc) and Sven (307.77 cc) in various protected structures (Table 4.12c). Similar results for increased fruit volume under polyhouse conditions have also been observed by Megharaja (2000), Kurubetta and Patil (2009) and Swamy (2013).

#### **4.11 Fruit rind thickness (cm)**

The different protected structures had significant influence on the fruit rind thickness among the green group hybrids and also the significant mean differences and their were significant interaction effects among hybrids (Table 4.1). NVPH and walk-in-tunnel recorded the maximum mean fruit rind thickness (0.82 cm) which was significantly followed by nethouse (0.79 cm) for different hybrids. Pasrella had the maximum fruit rind thickness (0.85 cm) in NVPH and Indra and Starlet had the minimum fruit rind thickness (0.78 cm) in nethouse. Under the different protected structures, overall maximum mean fruit rind thickness (0.83 cm) was recorded in Pasrella followed by both Indra and Starlet (0.80 cm) (Table 4.13a). Similar results were obtained by Kurubetta and Patil (2009), and Swamy (2013) for Indra cultivar under polyhouse.

Among the red group hybrids, the different growing structures had significant influence on the fruit rind thickness. Significant mean differences and their interaction effects among hybrids were also recorded significant for this character (Table 4.2). NVPH and walk-in-tunnel structures recorded maximum fruit rind thickness (0.87 cm) followed by nethouse (0.84 cm) for different hybrids. The maximum fruit rind thickness (0.89 cm) was recorded by Inspiration in NVPH and Bomby recorded the

**Table 4.13: Fruit rind thickness (cm) of capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	0.82	0.78	0.80	0.80
	Pasrella	0.85	0.82	0.83	0.83
	Starlet	0.80	0.78	0.82	0.80
Mean A		0.82	0.79	0.82	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.005	0.007		0.013	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	0.86	0.83	0.87	0.86
	Inspiration	0.89	0.85	0.87	0.87
	Mazillia	0.87	0.84	0.86	0.85
Mean A		0.87	0.84	0.87	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.008	0.006		0.012	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	0.87	0.80	0.85	0.84
	Bachata	0.90	0.84	0.89	0.87
	Sven	0.81	0.78	0.82	0.80
Mean A		0.86	0.80	0.85	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.004	0.003		0.005	

CD at P=0.05

minimum fruit rind thickness (0.83 cm) in nethouse. Overall maximum mean fruit rind thickness was recorded from Inspiration (0.87 cm) followed by Bomby (0.86 cm) and Mazillia (0.85 cm) in different protected structures (Table 4.13b).

Among the yellow group capsicum hybrids, the different growing structures had significant influence on the fruit rind thickness. Significant mean differences and their interaction effects among hybrids were also significant for this character (Table 4.3). NVPH recorded maximum mean fruit rind thickness (0.86 cm) which was significantly followed by walk-in-tunnel (0.85 cm) and nethouse (0.80 cm) for different hybrids. Bachata had the maximum fruit rind thickness (0.90 cm) in NVPH and Sven recorded minimum fruit rind thickness (0.78 cm) in nethouse. Overall maximum mean fruit rind thickness was recorded in Bachata (0.87 cm) followed by Orobelle (0.84 cm) and Sven (0.80 cm) under different protected structures (Table 4.13c). Similar findings for better fruit rind thickness under polyhouse conditions were also observed by Naik (2005), and Lone (2014).

#### **4.12 Shelf life (Days)**

There was a significant influence among growing structures namely NVPH, nethouse and walk-in-tunnel recorded in green colour capsicum hybrids, and significant mean differences and non-significant interaction effects were recorded for shelf life (days)(Table 4.1). Among the different growing protected structures, NVPH had recorded maximum significant mean shelf life (7.90) as compared to walk-in-tunnel (7.14) and nethouse (6.40) for different hybrids. Indra had longest shelf life (8.59) in NVPH and Starlet had minimal shelf life (6.00) in nethouse. Overall the maximum mean shelf life was recorded in Indra (7.83) which was significantly followed by Pasrella (6.96) and Starlet (6.64) in various protected structures (Table 4.14a). Similar findings for Indra were also reported by Kurubetta and Patil (2009)

Among the red group capsicum hybrids, the different growing structures had significant influence on the mean shelf life (days). Significant mean differences and their interaction effects among hybrids were also recorded significant for this character (Table 4.2). The average shelf life of fruits from NVPH (7.56) was recorded significantly maximum as compared to walk-in-tunnels (7.10) and nethouse (6.08). Inspiration recorded maximum shelf life (8.00) in NVPH and Mazillia had the

**Table 4.14: Shelf life (Days) of capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	8.59	7.00	7.90	7.83
	Pasrella	7.69	6.19	7.00	6.96
	Starlet	7.40	6.00	6.53	6.64
Mean A		7.90	6.40	7.14	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.074	0.095		NS	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	7.60	6.10	7.06	6.92
	Inspiration	8.00	6.20	7.40	7.20
	Mazillia	7.10	5.96	6.83	6.63
Mean A		7.56	6.08	7.10	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.090	0.122		0.212	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	7.10	6.00	6.76	6.62
	Bachata	7.50	6.43	7.13	7.02
	Sven	7.00	5.90	6.56	6.48
Mean A		7.20	6.11	6.82	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.138	0.073		NS	

CD at P=0.05



minimum shelf life (5.96) in nethouse. Overall the maximum shelf life was recorded by Inspiration (7.20) followed by Bomby (6.92) and Mazillia (6.63) under different protected structures (Table 4.14b).

Among the yellow group capsicum hybrids, NVPH, nethouse and walk-in-tunnel had significant influence on the shelf life of fruits. Significant mean differences and non-significant interaction effects were also recorded for different hybrids under study (Table 4.3). NVPH recorded maximum mean shelf life (7.20) followed by walk-in-tunnel (6.82) and nethouse (6.11). Fruits of Bachata had longest shelf life (7.50) in NVPH and Sven recorded minimum fruit shelf life (5.90) in nethouse. Overall fruits of Bachata had longest shelf life (7.02) followed by Orobelle (6.62) and Sven (6.48) under various protected structures (Table 4.14c). Similar findings on fruit shelf life were also reported by Rai *et al* (1995), and Kurubetta and Patil (2009).

#### **4.13 Total fruit yield per plant (kg)**

Among the green group hybrids, the different growing structures had significant influence on the total fruit yield per plant and significant mean differences and their interaction effects among hybrids were also significant (Table 4.1). The higher mean total fruit yield per plant (3.32 kg) was recorded in NVPH, which was significantly followed by the walk-in-tunnel (2.91 kg) and nethouse (2.33 kg) for different hybrids. Indra recorded higher total fruit yield per plant (3.62 kg) in NVPH and Starlet recorded lowest total fruit yield per plant (2.13 kg) in nethouse. Overall maximum mean total fruit yield per plant (3.08 kg) was recorded from Indra followed by Pasrella (2.82 kg) and Starlet (2.65 kg) under different protected structures (Table 4.15a).

The different growing structures had significant influence on the total fruit yield per plant among the red group hybrids. The significant mean differences and their interaction effects among hybrids were also significant for fruit yield (Table 4.2). The maximum mean total fruit yield per plant (2.54 kg) was recorded in NVPH followed by walk-in-tunnel (2.29 kg) and nethouse (1.99 kg). Inspiration recorded maximum total fruit yield per plant (2.81 kg) in NVPH and Bomby had minimum total fruit yield per plant (1.78 kg) in nethouse conditions. Overall higher total fruit yield per

**Table 4.15: Total fruit yield per plant (kg) of capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	3.62	2.58	3.04	3.08
	Pasrella	3.28	2.28	2.92	2.82
	Starlet	3.05	2.13	2.78	2.65
Mean A		3.32	2.33	2.91	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.06	0.05		0.10	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	2.29	1.78	2.05	2.04
	Inspiration	2.81	2.17	2.53	2.50
	Mazillia	2.51	2.02	2.30	2.28
Mean A		2.54	1.99	2.29	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.05	0.03		0.06	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	2.61	2.29	2.43	2.44
	Bachata	3.00	2.43	2.76	2.73
	Sven	2.43	1.92	2.04	2.13
Mean A		2.68	2.21	2.41	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.09	0.05		0.10	

CD at P=0.05

plant (2.50 kg) was recorded in Inspiration, followed by Mazillia (2.28 kg) and Bomby (2.04 kg) under different growing structures (Table 4.15b).

Among the yellow group capsicum hybrids, NVPH, nethouse and walk-in-tunnel had significant differences on the total fruit yield per plant and also significant mean differences and interaction effects were recorded significant due to different hybrids (Table 4.3). Maximum mean total fruit yield per plant (2.68 kg) was recorded from NVPH conditions which were significantly followed by walk-in-tunnel (2.41 kg) and nethouse (2.21 kg). Bachata had produced maximum total fruit yield per plant (3.00 kg) from NVPH and the poor total fruit yield per plant (1.92 kg) was recorded from Sven in nethouse. Overall performance among hybrid revealed that Bachata (2.73 kg) had produced maximum mean total fruit yield per plant followed by Orobelle (2.44 kg) and Sven (2.13 kg) under different protected structures (Table 4.15c). Present findings are in line with the findings of Naik (2005), Singh *et al* (2011), Halim and Islam (2013), and Lone (2014) under polyhouse conditions.

#### **4.14 Total fruit yield per square metre (kg)**

Among the green group hybrids the different protected structures had significant influence on the total fruit yield per square metre and there were significant mean differences and interaction effects among hybrids were also significant (Table 4.1). The maximum mean total fruit yield per square metre (9.96 kg) was recorded from NVPH followed by walk-in-tunnel (8.74 kg) and nethouse (6.99 kg) for different hybrids. Indra recorded maximum total fruit yield per square metre (10.86 kg) from NVPH and Starlet recorded minimum total fruit yield per square metre (6.39 kg) from the nethouse. The overall mean performance among hybrid revealed that Indra (9.24 kg) produced maximum (9.24 kg) total fruit yield per square metre followed by Pasrella (8.48 kg) and Starlet (7.96 kg) in different protected structures (Table 4.16a).

The different growing structures had significant influence on the total fruit yield per square metre among the red group hybrids and the significant mean differences and significant interaction effects among hybrids were also significant (Table 4.2). The maximum mean total fruit yield per square metre (7.62 kg) was recorded from NVPH followed by walk-in-tunnel (6.89 kg) and nethouse (5.99 kg) conditions for different hybrids. Inspiration had produced maximum total fruit yield per square

**Table 4.16: Total fruit yield per square metre (kg) of capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	10.86	7.75	9.13	9.24
	Pasrella	9.84	6.85	8.75	8.48
	Starlet	9.16	6.39	8.34	7.96
Mean A		9.96	6.99	8.74	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.18	0.17		0.30	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	6.89	5.36	6.16	6.13
	Inspiration	8.45	6.53	7.60	7.52
	Mazillia	7.53	6.08	6.92	6.84
Mean A		7.62	5.99	6.89	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.15	0.11		0.19	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	7.83	6.87	7.31	7.33
	Bachata	9.00	7.30	8.29	8.19
	Sven	7.30	5.78	6.13	6.40
Mean A		8.04	6.65	7.24	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.27	0.17		0.30	

CD at P=0.05

metre (8.45 kg) from NVPH while Bomby produced minimum (5.36 kg) from nethouse conditions. The overall mean performance among hybrids revealed that Inspiration (7.52 kg) recorded maximum total fruit yield per square metre (Table 4.16b) followed by Mazillia (6.84 kg) and Bomby (6.13 kg) under different protected structures.

Among the yellow group capsicum hybrids, the growing structures had significant influence on the total fruit yield per square metre and significant mean differences and their interaction effects were also recorded (Table 4.3). Maximum mean total fruit yield per square metre (8.04 kg) was recorded in NVPH followed by walk-in-tunnel (7.24 kg) and nethouse (6.65 kg) for different hybrids. Bachata had produced maximum total fruit yield per square metre (9.00 kg) from NVPH and Sven (5.78 kg) produced lowest under nethouse conditions. Among overall performance of the hybrids, for mean total fruit yield per square metre Bachata (8.19 kg) recorded highest followed by Orobelle (7.33 kg) and Sven (6.40 kg) under different protected structures (Table 4.16c). Similarly higher fruit yield kg/m<sup>2</sup> was also reported by Buoczowska (1990), Singh *et al* (2007), Singh *et al* (2011), and Lone (2014).

#### **4.15 Total fruit yield per hectare (Tonnes)**

Among the green group capsicum hybrids the different growing structures had significant influence on the total fruit yield per hectare (Tonnes) and significant mean differences and interaction effects among hybrids were also significant (Table 4.1). The highest mean total fruit yield (tonnes) per hectare (99.60) was recorded from NVPH which was significantly followed by the walk-in-tunnel (87.43) and nethouse (69.96) for different hybrids. Indra recorded highest total fruit yield per hectare (108.60) from NVPH and Starlet had lowest total fruit yield per hectare (63.90) from the nethouse conditions. Overall higher mean total fruit yield per hectare (92.46) was recorded from Indra followed by Pasrella (84.86) and Starlet (79.66) under different protected structures (Table 4.17a).

The different growing structures had significant influence on the total fruit yield per hectare among the red group hybrids. The significant mean differences and their significant interaction effects among hybrids were also significant for total fruit yield (Table 4.2). Higher mean total fruit yield per hectare (76.23) was recorded from

**Table 4.17: Total fruit yield per hectare (Tonnes) of capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	108.60	77.50	91.30	92.46
	Pasrella	98.50	68.50	87.60	84.86
	Starlet	91.70	63.90	83.40	79.66
Mean A		99.60	69.96	87.43	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	1.85	1.78		3.09	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	68.90	53.60	61.60	61.36
	Inspiration	84.50	65.30	76.00	75.26
	Mazillia	75.30	60.80	69.20	68.43
Mean A		76.23	59.90	68.93	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	1.56	1.13		1.96	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	78.30	68.70	73.10	73.36
	Bachata	90.00	73.00	82.90	81.96
	Sven	73.00	57.80	61.30	64.03
Mean A		80.43	66.50	72.43	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	2.75	1.75		3.03	

CD at P=0.05

NVPH followed by walk-in-tunnel (68.93) and nethouse (59.90). Maximum total fruit yield per hectare (84.50) was recorded from Inspiration in NVPH and the lowest total fruit yield per hectare (53.60) was recorded from Bomby under nethouse conditions. Inspiration had maximum mean total fruit yield per hectare (75.26) followed by Mazillia (68.43) and Bomby (61.36) under different growing structures (Table 4.17b).

Among the yellow group capsicum hybrids, different growing structures had significant influence on the total fruit yield per hectare. Significant mean differences and interaction effects were also significant for different hybrids (Table 4.3). Significantly highest mean total fruit yield per hectare (80.43) was recorded in NVPH followed by walk-in-tunnel (72.43) and nethouse (66.50). Bachata had highest total fruit yield per hectare (90.00) from NVPH and Sven had lowest total fruit yield per hectare (57.80) from nethouse structure. Among overall performance of the hybrids, for mean total fruit yield per hectare Bachata (81.96) was recorded highest followed by Orobelle (73.36) and Sven

(64.03) under different protected structures (Table 4.17b). Similar findings for better fruit yield per unit area were also observed by Brar *et al* (2005), Naik (2005), Zende (2008), Singh *et al* (2011), and Kumar and Chandra (2014).

#### **4.16 Tolerance to major pests**

Among the green group hybrids of capsicum, the different growing structures had significant influence on the tolerance to major pests, i.e., thrips and mites; and also significant mean differences and interaction effects among hybrids were significant (Table 4.1). The highest mean tolerance (%) to major pests (2.01) was recorded from NVPH followed by walk-in-tunnel (2.30) and nethouse (3.02) for different hybrids. Pasrella showed maximum tolerance (1.86) NVPH and Indra (3.10) showed lowest tolerance in nethouse structure. Overall higher mean tolerance to major pests (2.28) was recorded from Pasrella followed by Indra (2.51) and Starlet (2.53) under different protected structures (Table 4.18a).

The different growing structures had significant influence on the tolerance to major pests (%) among the red group hybrids and significant mean differences and non-significant interaction effects among hybrids were also recorded (Table 4.2).

**Table 4.18: Infestation of major pests on capsicum hybrids influenced by different protected structures**

**a) Green group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Green Group	Indra	2.10	3.10	2.33	2.51
	Pasrella	1.86	2.93	2.06	2.28
	Starlet	2.06	3.03	2.50	2.53
Mean A		2.01	3.02	2.30	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.08	0.06		0.11	

**b) Red group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Red Group	Bomby	2.20	3.13	2.26	2.53
	Inspiration	1.93	2.86	2.00	2.26
	Mazillia	2.06	3.00	2.10	2.38
Mean A		2.06	3.00	2.12	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.10	0.05		NS	

**c) Yellow group hybrids**

Name of Group	Name of Hybrid (B)	Name of structure (A)			Mean B
		Naturally ventilated polyhouse	Net House	Walk-in-tunnel	
Yellow Group	Orobelle	2.16	3.06	2.26	2.50
	Bachata	2.06	2.83	2.23	2.37
	Sven	2.20	3.00	2.36	2.52
Mean A		2.14	2.96	2.28	
CD	Factor (A)	Factor (B)		Interaction (A x B)	
	0.09	0.08		NS	

CD at P=0.05



Maximum mean tolerance to major pests (2.06) was recorded in NVPH followed by walk-in-tunnel (2.12) and nethouse (3.00) for different hybrids. Inspiration showed maximum tolerance to major pests (1.93) in NVPH. Overall Inspiration recorded maximum mean tolerance to major pests (2.26) followed by Mazillia (2.38) and Bomby (2.53) under different growing structures (Table 4.18b).

Among the yellow group of capsicum hybrids, NVPH, nethouse and walk-in-tunnel had significant influence on the tolerance to major pests (%). Significant mean differences and non-significant interaction effects were also recorded for different hybrids (Table 4.3). NVPH recorded maximum tolerance to major pests (2.14) followed by walk-in-tunnel (2.28) and nethouse (2.96) for different hybrids. Bachata had maximum tolerance to major pests (2.06) in NVPH. Overall Bachata had higher tolerance to major pests (2.37) followed by Orobelle (2.50) and Sven (2.52) showed under different protected structures (Table 4.18c). Similar findings for lesser infestation of insect-pest under protected conditions were reported by Yosepha (2007), Singh *et al* (2003), Singh *et al* (2005), and Singh and Sirohi (2006).

#### **4.17 Temperature ( $^{\circ}$ C)**

Climatic conditions under protected structures were improved as compared to open cultivation conditions. It was observed that the walk-in-tunnel structure had the maximum temperature  $47.5^{\circ}$ C in the month of May as compared to  $39.2^{\circ}$ C under unprotected conditions. Similarly when the temperature of open conditions fell down to 19.2 in the month of December, the temperature in walk-in-tunnel and NVPH ( $29.9^{\circ}$ C and  $27.5^{\circ}$ C) remained high, which resulted in good crop growth (Table 4.19). The temperature range was found  $1.5-3^{\circ}$ C higher in nethouse,  $5-7^{\circ}$ C higher in NVPH, and  $7-9^{\circ}$ C higher in walk-in-tunnel as compared to unprotected cultivation conditions.

Favourable temperature regime has great impact on the flower initiation, percent fruit set and the total fruit yield. The variation in the flower initiation and fruit setting in different hybrids under protected environment was due to an interactive response of genetic constitution and favourable climate especially temperature. Similar findings were reported by Basavaraja *et al* (2003), and Sabir and Singh (2013).

**Table 4.19: Comparison of mean monthly temperature (°C) during 2014-15 & 2015-16 cropping seasons.**

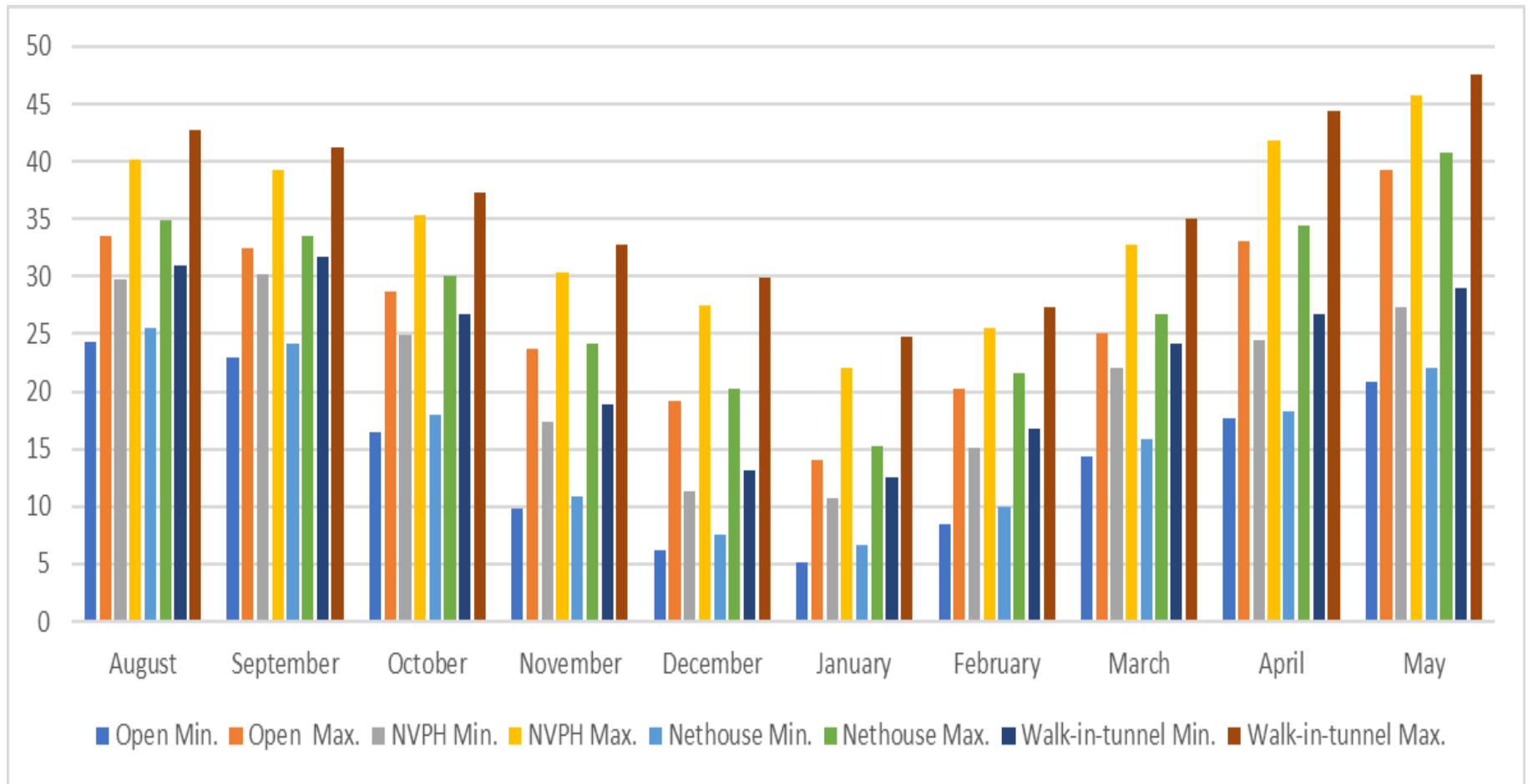
Name of month	Open Conditions		NVPH		Nethouse		Walk-in-tunnel	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
August	24.3	33.5	29.8	40.1	25.5	34.9	30.9	42.8
September	23	32.4	30.2	39.3	24.1	33.5	31.7	41.2
October	16.5	28.7	24.9	35.4	18	30.1	26.8	37.3
November	9.8	23.7	17.4	30.4	10.9	24.2	18.9	32.7
December	6.2	19.2	11.4	27.5	7.5	20.2	13.1	29.9
January	5.1	14.1	10.7	22.1	6.6	15.3	12.6	24.8
February	8.5	20.3	15.1	25.5	9.9	21.6	16.8	27.4
March	14.4	25.1	22	32.8	15.8	26.7	24.2	35.1
April	17.6	33.1	24.5	41.9	18.3	34.5	26.7	44.4
May	20.8	39.2	27.4	45.7	22.1	40.8	29	47.5

#### **4.18 Relative humidity (%)**

Relative humidity in protected structures was found higher as compared to unprotected conditions. In NVPH the maximum humidity 90.1% was recorded in the month of January and lowest 72.7% in the month of May (Table 4.20). Similar trends were recorded in walk-in-tunnel with the higher relative humidity 94.5% in the month of January which was highest among all protected structures and lowest 79.7% in the May. The nethouse structure also recorded maximum humidity of 88.5% in the month of January.

The relative humidity was directly associated with the temperature range in the growing structure. As the temperature fell down in winter season (December, January), the relative humidity started increasing. When the temperature started increasing in the structure in the month of April and May, the relative humidity started decreasing. Prevalence of particular root zone temperature ranging 20-22°C along with high relative humidity about 80% has high influence on capsicum plant growth and development. Similar results also been obtained by Basavaraja *et al* (2003), and Sabir and Singh (2013).

**Figure 4.1: Comparison of mean monthly temperature (°C) during 2014-15 & 2015-16 cropping seasons.**



**Table 4.20: Comparison of mean monthly relative humidity (%) during 2014-15 & 2015-16 cropping seasons.**

Name of month	Open Conditions		NVPH		Nethouse		Walk-in-tunnel	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
August	57.6	76.7	74.4	80.3	60.4	77.4	82.5	89.7
September	62	77.2	75.5	82.5	67.1	78.3	85.4	90.9
October	60.1	72.5	74.9	81.8	66.3	74.8	84.7	91.2
November	56.3	70.1	75.4	82.3	61.1	73.5	83.6	91.1
December	67.9	81.2	81.7	89.6	73.5	84.1	88.2	93.9
January	68.5	83.5	84.6	90.1	73.6	88.5	89	94.5
February	64.2	76.8	77.8	81.1	68.9	78.4	83.6	88.4
March	60.5	74.3	72.2	78.7	65.4	75.7	79.8	85.5
April	59.4	68	70.5	76.2	63.8	70.3	77.2	82.3
May	47.8	62.5	68.4	72.7	53.2	63.9	75.5	79.7

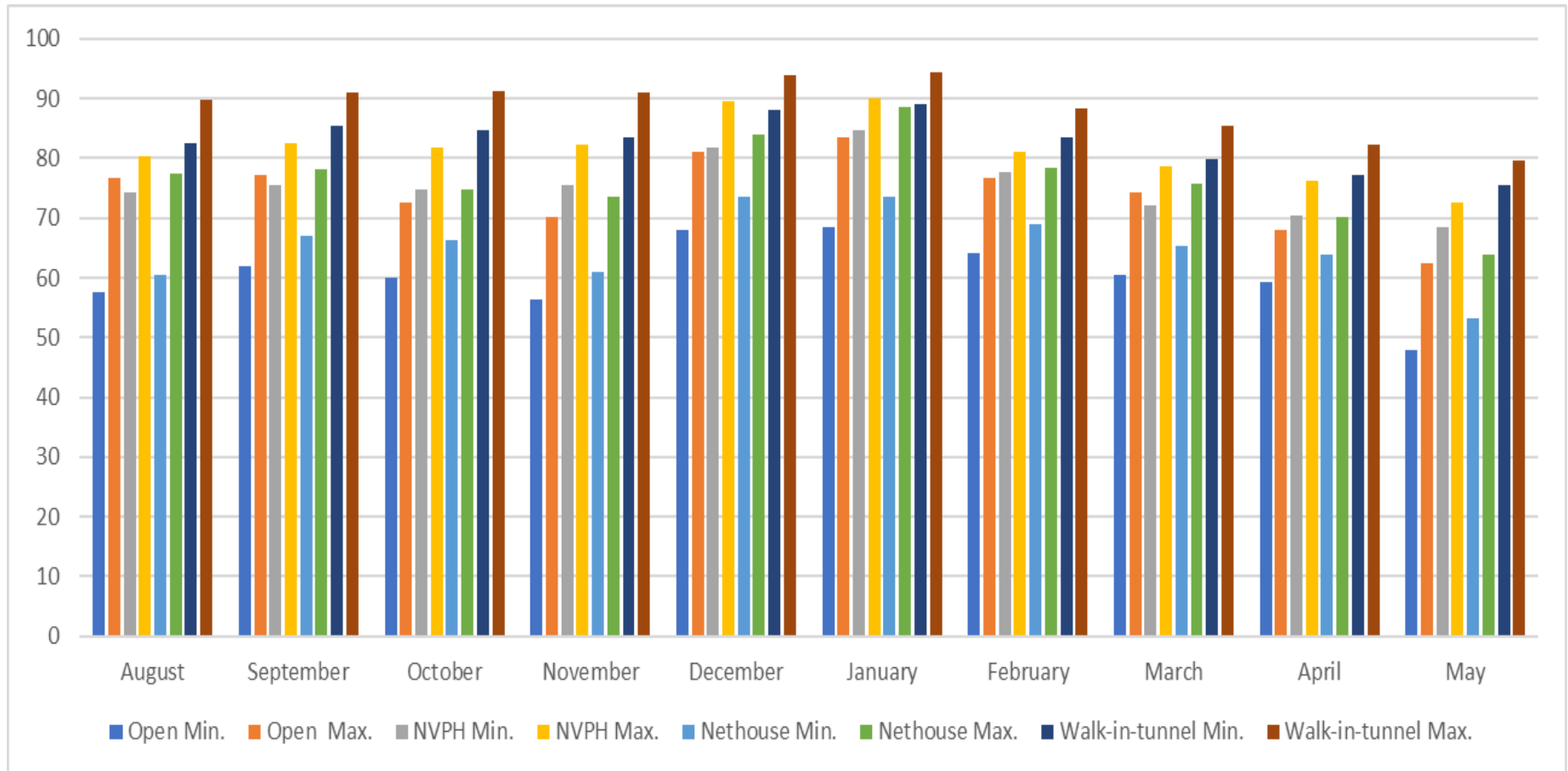
#### **4.19 Light intensity (klux)**

Light is required for the process of photosynthesis which is essential for production of plant dry matter. The light intensity (56.67 klux) was recorded maximum under protected structures in the month of March and minimum (43.85 klux) in the month of December. It was observed that the light intensity was higher during longer sun shine hour and vice-a-versa. It led to the crop growth and development activity to take place due to improved stomata functioning. Similar findings were obtained by Ilic *et al* (2011), Singh *et al* (2011), and Ombodi *et al* (2015).

#### **4.20 Economics**

Economics of Sweet pepper production under different protected structures was worked out by considering the market price of inputs and produce. The following formula was used to calculate the cost: benefit ratio:-

**Figure 4.2 : Comparison of mean monthly relative humidity (%) during 2014-15 & 2015-16 cropping seasons.**



Net returns (Rs/500 m<sup>2</sup>) = Gross returns (Rs/500 m<sup>2</sup>) - cost of cultivation (Rs/500 m<sup>2</sup>)

$$\text{Benefit: Cost Ratio} = \frac{\text{Gross returns (Rs/500 m}^2\text{)}}{\text{Cost of cultivation (Rs/500 m}^2\text{)}}$$

Nethouse and walk-in-tunnel units were established on an area of 500 m<sup>2</sup> each. NVPH structure was established over an area of 2000 m<sup>2</sup>. The fixed and variable costs for the establishment and maintenance of these structures for 500 m<sup>2</sup> area were calculated from the total costs of 2000 m<sup>2</sup> area units. The fixed costs of protected structures were calculated as Rs. 42200/- for NVPH, Rs. 35000/- for nethouse and Rs. 30000/- for walk-in-tunnel per year. Over an area of 500 m<sup>2</sup>, approximately 1500 seedlings were transplanted at a spacing distance of 40 x 30 cm between rows and plants respectively with 5 beds under each growing structure.

The total cost of cultivation for different hybrids under different protected structures were calculated by adding up fixed, repair and maintenance cost of structures, and variable costs of crop cultivation like seedling cost, irrigation & Fertigation cost, chemicals (insecticide and fungicide) cost, cost of materials used for mulching, cost of farm labour used for cultural operations from transplanting till the end of cropping season etc. It was estimated that the total cultivation cost varied with different growing units like Rs. 124310/- for NVPH, Rs. 114448/- for nethouse and Rs. 111736/- for walk-in-tunnel for green group hybrids but remained same for all three different hybrids under the respective structure (Table 4.21). For both the red and yellow colour hybrids group the total cultivation cost was estimated as Rs. 131060/- for NVPH, Rs. 121198/- for nethouse and Rs. 118486/- for walk-in-tunnel structures.

The gross returns from 500 m<sup>2</sup> area accommodating 1500 plants was calculated by considering the total fruit yield per plant of each of the different colour group hybrid under various protected structures separately to work out total net returns of each hybrid. The results revealed that among green group hybrids, Indra had maximum net returns of Rs. 65740/- from NVPH followed by the same hybrid from walk-in-tunnel of Rs. 48039/- which resulted in highest B:C ratio of 1:1.53 and 1:1.43 from NVPH

**Table 4.21: Detailed cost of cultivation for Green, Red, and Yellow colour group hybrids (Average of two seasons 2014-15 & 2015-16) grown on 500 m<sup>2</sup> under various protected structures.**

**I. Capsicum cultivation under an area of 500 m<sup>2</sup>**

Name of hybrids	Number of beds	Number of plants/bed	Total number of plants/500 m <sup>2</sup>	Duration of crop (from transplanting)
All green, red, and yellow group	5	300	1500	9 months (September to May)

**II. Green group hybrids**

Sr. No.	Particular	NVPH			Nethouse			Walk-in-tunnel		
		Indra	Pasrella	Starlet	Indra	Pasrella	Starlet	Indra	Pasrella	Starlet
<b>I</b>	<b>Fixed cost of structure (Rs.) Annually</b>	42200	42200	42200	35000	35000	35000	30000	30000	30000
<b>II</b>	<b>Variable cost (Rs.)</b>									
i.	Seedling cost @ Rs. 2.50 for 1500 seedlings per 500 m <sup>2</sup> (including seed and nursery management)	3750	3750	3750	3750	3750	3750	3750	3750	3750
ii.	Land preparation	2000	2000	2000	2000	2000	2000	2000	2000	2000
iii.	Fertilizers and irrigation	25000	25000	25000	25000	25000	25000	25000	25000	25000
iv.	Chemical cost	400	400	400	500	500	500	400	400	400
v.	Mulching (30 micron) silver black	2000	2000	2000	2000	2000	2000	2000	2000	2000
vi.	Labour (12 days/month@ Rs. 260/day/person) for 9 months	28080	28080	28080	28080	28080	28080	28080	28080	28080
vii.	Annual repair and Structure maintenance	20880	20880	20880	18118	18118	18118	20506	20506	20506
	<b>Total</b>	<b>124310</b>	<b>124310</b>	<b>124310</b>	<b>114448</b>	<b>114448</b>	<b>114448</b>	<b>111736</b>	<b>111736</b>	<b>111736</b>

...Contd

... Contd

**III. Red group hybrids**

Sr. No.	Particular	NVPH			Nethouse			Walk-in-tunnel		
		Bomby	Inspiration	Mazillia	Bomby	Inspiration	Mazillia	Bomby	Inspiration	Mazillia
<b>I</b>	<b>Fixed cost of structure (Rs.) annually</b>	42200	42200	42200	35000	35000	35000	30000	30000	30000
<b>II</b>	<b>Variable cost (Rs.)</b>									
i.	Seedling cost @ Rs. 7.00 for 1500 seedlings per 500 m <sup>2</sup> (including seed and nursery management)	10500	10500	10500	10500	10500	10500	10500	10500	10500
ii.	Land preparation	2000	2000	2000	2000	2000	2000	2000	2000	2000
iii.	Fertilizers and irrigation	25000	25000	25000	25000	25000	25000	25000	25000	25000
iv.	Chemical cost	400	400	400	500	500	500	400	400	400
V	Mulching (30 micron) silver black	2000	2000	2000	2000	2000	2000	2000	2000	2000
vi.	Labour (12 days/month@ Rs. 260/day/person) for 9 months	28080	28080	28080	28080	28080	28080	28080	28080	28080
vii.	Annual repair and Structure maintenance	20880	20880	20880	18118	18118	18118	20506	20506	20506
	<b>Total</b>	<b>131060</b>	<b>131060</b>	<b>131060</b>	<b>121198</b>	<b>121198</b>	<b>121198</b>	<b>118486</b>	<b>118486</b>	<b>118486</b>

...Contd



... Contd

**IV. Yellow group hybrids**

Sr. No.	Particular	NVPH			Nethouse			Walk-in-tunnel		
		Indra	Pasrella	Starlet	Indra	Pasrella	Starlet	Indra	Pasrella	Starlet
<b>I</b>	<b>Fixed cost of structure (Rs.) annually</b>	42200	42200	42200	35000	35000	35000	30000	30000	30000
<b>II</b>	<b>Variable cost (Rs.)</b>									
i.	Seedling cost @ Rs. 7.00 for 1500 seedlings per 500 m <sup>2</sup> (including seed and nursery management)	10500	10500	10500	10500	10500	10500	10500	10500	10500
ii.	Land preparation	2000	2000	2000	2000	2000	2000	2000	2000	2000
iii	Fertilizers and irrigation	25000	25000	25000	25000	25000	25000	25000	25000	25000
iv	Chemical cost	400	400	400	500	500	500	400	400	400
v	Mulching (30 micron) silver black	2000	2000	2000	2000	2000	2000	2000	2000	2000
vi	Labour (12 days/month@ Rs. 260/day/person) for 9 months	28080	28080	28080	28080	28080	28080	28080	28080	28080
vVii	Annual repair and Structure maintenance	20880	20880	20880	18118	18118	18118	20506	20506	20506
	<b>Total</b>	<b>131060</b>	<b>131060</b>	<b>131060</b>	<b>121198</b>	<b>121198</b>	<b>121198</b>	<b>118486</b>	<b>118486</b>	<b>118486</b>

**Table 4.22: Economics of various capsicum hybrids under different protected structures grown on 500 m<sup>2</sup> (Average of two seasons 2014-15 & 2015-16) (B:C ratio )**

Protected Structure	Name of Hybrids	Fruit yield /500 m <sup>2</sup> (kg)	Cost of cultivation/ 500 m <sup>2</sup> (Rs.)	Gross income (Rs.)	Net income (Rs.)	B:C ratio
<b>Green Group*</b>						
NVPH	Indra	5430	124310	190050	65740	1:1.53
	Pasrella	4920	124310	172200	47890	1:1.39
	Starlet	4580	124310	160300	35990	1:1.29
Nethouse	Indra	3875	114448	135625	21177	1:1.19
	Pasrella	3425	114448	119875	5427	1:1.05
	Starlet	3195	114448	111825	-2623	1:0.98
Walk-in-tunnel	Indra	4565	111736	159775	48039	1:1.43
	Pasrella	4375	111736	153125	41389	1:1.37
	Starlet	4170	111736	145950	34214	1:1.31
<b>Red Group**</b>						
NVPH	Bomby	3445	131060	172250	41190	1:1.31
	Inspiration	4225	131060	211250	80190	1:1.61
	Mazillia	3765	131060	188250	57190	1:1.44
Nethouse	Bomby	2680	121198	134000	12802	1:1.11
	Inspiration	3265	121198	163250	42052	1:1.35
	Mazillia	3040	121198	152000	30802	1:1.25
Walk-in-tunnel	Bomby	3080	118486	154000	35514	1:1.30
	Inspiration	3800	118486	190000	71514	1:1.60
	Mazillia	3460	118486	173000	54514	1:1.46
<b>Yellow Group**</b>						
NVPH	Orobelle	3915	131060	195750	64690	1:1.49
	Bachata	4500	131060	225000	93940	1:1.72
	Sven	3650	131060	182500	51440	1:1.39
Nethouse	Orobelle	3435	121198	171750	50552	1:1.42
	Bachata	3650	121198	182500	61302	1:1.51
	Sven	2890	121198	144500	23302	1:1.19
Walk-in-tunnel	Orobelle	3655	118486	182750	66264	1:1.54
	Bachata	4145	118486	207250	88764	1:1.75
	Sven	3065	118486	153250	34764	1:1.29

\*Sale rate of capsicum (Green coloured) produce Rs. 35/- per kg

\*\* Sale rate of capsicum (Red & Yellow coloured) produce Rs. 50/- per kg

and walk-in-tunnel, respectively as compared to hybrids Pasrella and Starlet (Table 4.22).

Among red group hybrids, Inspiration had maximum net returns of Rs. 80190/- from NVPH structure followed by the same hybrid from walk-in-tunnel for Rs. 71514/- as compared to Bomby and Mazillia. Inspiration also had the highest B:C ratio of 1:1.61 from NVPH and 1:1.60 from walk-in-tunnel (Table 4.22).

Among the yellow colour group hybrids, Bachata gained higher net returns of Rs. 93940/- and 88764/- from NVPH and walk-in-tunnel structures, respectively as compared to other hybrids namely Orobelle and Sven. However, Bachata gained maximum B:C ratio of 1:1.75 from walk-in-tunnel followed by NVPH having B:C ratio of 1:1.72 (Table 4.22). Similarly higher net returns and B:C ratio of capsicum grown under protected conditions was observed by Ghosal and Das (2012), Sreedhara *et al* (2013), Lone (2014), and Kumar *et al* (2016).

Protected cultivation of capsicum has offered a new dimension to produce more and more from a limited area. Apart from the decreasing land holdings, rapid urbanization, biodiversity constraints and ever-increasing demand for vegetables, greenhouse cultivation emerged as the best alternate to obtain prolonged fruiting span, off-season and year round production of vegetables.

Plant growth and development in protected structures mainly depends upon the soil structure, so enough care should be undertaken while soil preparation. Soil preparation comprises field practices like soil sanitation, solarization, mulching. Soil solarization in hot summer was practiced in this investigation to reduce soil-borne pathogens by soil-heating effects, increased growth response of plants, control of weeds and insect pests. Similar findings for crop cultivation in greenhouse conditions were reported by Sesveren *et al.* (2011), and Fenoll *et al.* (2010). Soil treatment also improves the soil microbial activities and enhanced nitrogen uptake by the plants resulting in higher yields.

In the present decade farming system is suffering from depletion of precious natural resources like groundwater exploitation and quality irrigation water for crop cultivation. To overcome these constraints Stanghellini (1992) observed that efficient water usage can be achieved through protected cultivation as compared to open field

conditions. It was observed that among the various irrigation techniques, drip irrigation technology has helped in using water efficiently as well as resulted in reducing diseases that develop in rather moist conditions under the protected structures. In the present investigation all the essential nutrients were supplied through fertigation, i.e., irrigation combined with fertilizer application which allowed precise and homogeneous application of nutrients in the root zone area. Similarly, Sonneveld *et al.* (1991) suggested that the adequate concentration of the essential nutrient elements in the irrigation water is necessary to fetch high fruit yield and this practice also helped to protect environment by avoiding unnecessary usage of nutrient elements through other means of irrigation techniques.

As the plant density varied with the different capsicum hybrids and growing conditions, many reports in capsicum suggested that the plant density arrangement had greatly influenced the vegetative growth and fruit development process which directly contribute to the higher fruit yield per unit of area. Therefore, in the present study plant distance was kept at 40 x 30 cm between rows and plants respectively. Approximately 1500 plants in 500 square metre areas were planted by adopting this arrangement, which is sufficient for the proper utilization of land and space over a unit of area for fetching high returns. Mantur *et al* (2007) also reported maximum fruit yield, numbers of fruits per plant, fruit weight when planted at closer spacing of 45 x 30 cm compared to a relatively wider spacing of 45 x 45 cm. Similarly, Zende (2008), and Kumar and Chandra (2014) reported closer spacing of 45 x 30 cm for excellent quality and higher fruit yield under polyhouse. Lone (2014) also recorded maximum fruit yield 844.0 kg/100m<sup>2</sup> under closer spacing of 30 x 45 cm and it showed maximum net returns (Rs. 16525) and benefit: cost ratio (1:1.39) with two shoots per plant

In the present investigation silver black polyethylene mulch (30 micron thickness) was used to minimize weed infestation and to conserve soil moisture for better growth and development of capsicum plants for obtaining more crop productivity per unit area. Similar findings were reported by Bowen and Frey (2002), when capsicum grown using polyethylene mulch resulted larger and more productive fruit with thicker pericarp and higher water content. In another study Dhaliwal *et al* (2017) also reported maximum number of fruits per plant, fruit weight, early and marketable fruit

yield, and total fruit yield were obtained in the polyhouse while using black polythene mulch.

Among the various protected structures for the cultivation of green group hybrids under study namely Indra, Pasrella, and Starlet, the naturally ventilated polyhouse (NVPH) structure had proven best as compared to nethouse and walk-in-tunnel for vegetative character like maximum plant height (124.52 cm). It also contributed to the early fruit harvest (83.34 days), however, the first flower initiation (43.54 days) was observed early in walk-in-tunnel. Crop yield parameters like number of fruits per plant (19.10), percent fruit set (44.15 %), individual fruit weight (176.41), total fruit yield per plant (3.32 kg), total fruit yield per square metre (9.96 kg), and total fruit yield per hectare (99.60 tonnes) were recorded maximum from NVPH. Moreover, NVPH had appreciable influence on the fruit quality traits like that of fruit volume, fruit rind thickness (0.82 cm), and fruit shelf life (7.90 days). However, walk-in-tunnel showed better influence on the fruit length (9.36 cm) and fruit diameter (7.17 cm). Increase in height was might be due to partial modification of natural environment and ambient micro-climatic conditions surrounding the plants. In other means this might be due to enhanced photosynthesis and respiration in the polyhouse. Higher fruit length, fruit breadth, individual fruit weight and fruit volume were also recorded maximum with capsicum grown in greenhouse. Zende (2008) also recorded highest total marketable fruit yield with more excellent quality and export grade fruits when crop grown in polyhouse.

Hybrid Indra was found best for early flower initiation (41.93 days), maximum number of fruits per plant (21.49), fruit diameter (7.50 cm), fruit shelf life (8.59 days), and total fruit yield per plant (3.62 kg). Rai *et al* (1995) also reported longer shelf life of produce harvested from hybrids when grown under polyhouse as compared to open conditions. Similar findings were reported by Megharaja (2000) for higher plant height and total number of fruits per plant in capsicum grown in polyhouse condition compared to open condition in capsicum cv. Indra. After that Kurubetta and Patil (2009) concluded that the parametres like earliest flower initiation, first fruit harvesting and maximum fruit set, fruit weight, fruit volume, fruit rind thickness and fruit shelf life were significantly maximum under naturally ventilated polyhouse than naturally ventilated shadowhall. They also reported that among the hybrids, Indra

recorded maximum fruit shelf life (8.60 days). In another study, Swamy (2013) reported cv. Indra possessed minimum days taken for first flower initiation, maximum fruit width, and maximum number of fruits per plant.

Three different red group hybrids under this study, i.e., Bomby, Inspiration, and Mazillia were greatly influenced by the growing structures. NVPH had high influence on the plant height (103.74 cm), number of fruits per plant (12.54), percent fruit set (41.13%), individual fruit weight (208.78 g), fruit volume, fruit rind thickness (0.87 cm), fruit shelf life (7.56 days), total fruit yield per plant (2.54 kg), total fruit yield per square metre (7.62 kg), and total fruit yield per hectare (76.23 tonnes). However, walk-in-tunnel influenced earliness with respect to days taken to first flower initiation (45.75 days), and first fruit harvest (109.20 days). It also influenced fruit length and fruit diameter. By producing ultimate higher fruit yield per unit area, NVPH was superior over walk-in-tunnel and nethouse structures for red group hybrids. Among different hybrids, Inspiration showed its superiority for early flower initiation (42.33 days), early fruit harvest (105.83 days), higher number of fruits per plant (13.19), percent fruit set (42.43%), fruit length (9.70 cm), fruit diameter (8.23 cm), individual fruit weight (216.53 g) which led to higher fruit yield per plant (2.81 kg); per square metre; and per hectare (84.50 tonnes). Bomby exhibited higher plant height. Moreover, Inspiration had maximum fruit rind thickness (0.89 cm) which led to longer shelf life (8.0 days) of produce as compared to other hybrids of this group.

Among the yellow coloured capsicum's hybrids group the plant growing structures showed significant influence on the performance of different hybrids, i.e., Orobelle, Bachata, and Sven. NVPH ranked first for maximum fruit yield attributing parametres like number of fruits per plants (15.26), percent fruit set (40.26%), individual fruit weight (176.61 g), total fruit yield per plant (2.68 kg); per square metre (8.04 kg); and per hectare. It had great impact on the quality traits also like fruit volume, fruit rind thickness (0.86 cm), longer fruit shelf life (7.0 days) etc. However, walk-in-tunnels influenced plant height (106.31 cm), first flower initiation (46.60 days), first fruit harvest (100.7 days), fruit length (8.91 cm), and fruit diameter (7.41 cm). Among different hybrids, Bachata ranked first over Orobelle, and Sven for all the plant growth parametres, fruit earliness, fruit yield, and fruit quality related traits except for number of fruits per plant which was found maximum in Sven. In a study Farooq *et al*

(2015) studied influence of protected structure on growth and fruit yield of five capsicum hybrids namely Orobelle, Figaro, Green Beauty, Mighty and Capistrano under plastic tunnel. They found Orobelle superior for individual fruit weight and total fruit yield. Similar results were observed by Malshe *et al* (2016). They compared the open field and polyhouse conditions and concluded that Orobelle had maximum fruit weight (76.48g) and fruit yield (2.384 kg) under polyhouse. In contrary to this the present investigation study revealed that with respect to these parametres Bachata was found more superior than Orobelle.

The varied number of fruits per plants and individual fruit weight is genetically controlled. Although, it is the interaction of the heredity and ambient climatic conditions, i.e. temperature, relative humidity and light etc. during the cropping period which influenced the plant growth and development. Previously, Sood and Kaul (2006) concluded that the number of fruits per plant had direct effect on fruit yield in bell pepper. Despite this, the present investigation study found that the number of fruits per plant and individual fruit weight collectively contributed to higher fruit yield per plant. Sabir and Singh (2013) also reported that morphologically capsicum plant's main stem, after having 9-13 leaves, naturally developed two shoots which continued producing a terminal flower and two side shoots at every internode. They further reported that the fruit setting depends on optimum light, low temperature and increased CO<sub>2</sub> concentration.

In open conditions during winter months there are chances of occurrence of frost along with low temperature, whereas high temperature and low relative humidity prevails during hot summer months. Severe attack of insect-pest and viral diseases resulted in poor plant growth and fruit development. In contrary to this, it is observed that favourable environmental conditions prevailing in polyhouse helped in better growth of roots and shoots, which directly improved the fruit yield attributing parametres like number of fruits per plant, individual fruit weight, fruit rind thickness, fruit length and fruit breadth leading to higher total fruit yield per plant and per hectare. Similar conclusion was also reported by Naik (2005), and Bhatt and Srinivasa Rao (1993). In another study Singh *et al* (2007) also reported attack of aphid, white fly and leaf curl virus at an early phase of seedlings in open conditions resulted in

stunted plant growth, poor fruit set and heavy flower drop, unmarketable fruit yield due to high temperature and low relative humidity.

Higher fruit yield under protected conditions was the result of increased plant height, fruit length, fruit weight and fruit girth, longer fruiting span etc. It might be due to the high rate of carbon dioxide released at night and utilization at day time which increased the rate of photosynthesis in the polyhouse. This region (Punjab) situated in the North-west of Indian sub-continent represent sub-tropical type of climatic conditions, therefore it possesses three peculiar characteristics, i.e., having extremes of temperature, i.e., sub-optimal temperature ranging 0-3.5°C during winter months (end October to February) and maximum of 45°C and above during summer months (April to June) and the rainy season from July to September. Under such extremes protected cultivation emerged as an alternative to raise off-season crop of capsicum during cold winters. Utilization of UV stabilized plastic films in protected cultivation allowing only infra-red radiations to enter the greenhouse. Such radiations keeps the inside environment of greenhouse favourable for crop growth and development by releasing geo-thermal radiations. Similarly, Singh *et al* (2011); and Basavaraja *et al* (2003) reported that the higher fruit yield in polyhouse and polytunnel was due to the improved micro-climate surrounding the plant which improved its growth and productivity. They concluded that the temperature range was found 3-4<sup>0</sup>C higher in polyhouse, and 1-2<sup>0</sup>C higher in polytunnel as comparative to unprotected cultivation conditions. Sabir and Singh (2013) also observed that plant growth and development of capsicum is highly dependent on temperature, particularly the root temperature ranging from 20-22°C along with high relative humidity ranging about 80%.

Murthy *et al* (2009) reported that the quality of fruits under polyhouse was found to be more superior in terms of its size, colour and shine and broke the seasonal barriers of crop production throughout the year. Similarly, Ghosal and Das (2012) found 2.34 times more fruit yield of capsicum per square metre than open field condition. Early flowering and fruiting and increased plant height were observed in the greenhouse as compared to the open field conditions.



Significant influence of protected structures on plant growth and fruit yield of capsicum with enhanced plant height compared to open field was found by Halim and Islam (2013). They revealed that maximum fruit yield per plant was obtained in poly house (160.4% higher than that of open field condition) followed by the second highest yield in poly tunnel.

It was noticed that the percent attack of insect-pest was very low under the protected structure. Covered nature of protected structure, i.e., polythene sheet and mesh sheet etc. act as physical barrier to insect-pest entry. However unprotected cultivation conditions are highly affected by insect-pest attack which leads to lower total and marketable fruit yield per unit area as compared to protected cultivation. Similar findings were reported by Singh *et al* (2003). This advantage contributed to the high economic returns by reducing pesticide inputs cost as compared to unprotected conditions (Singh *et al* 2005). Thus, the protected cultivation facilitates the Integrated Pest Management for insect-pest control. Singh and Sirohi (2006) concluded that anti insect proof nethouse was effective for virus free vegetable nursery raising during rainy season when whitefly population build up is very high in the environment. The results of the present study revealed that the NVPH had shown higher tolerance to major insect-pest of capsicum, i.e., white fly and thrips as compared to walk-in-tunnel and nethouse for green, red, and yellow colour hybrids.

Protected cultivation of capsicum is the best practice to grow off-season crop to meet the consumer's demand and daily nutrition requirements. When the environmental temperature falls down in the winter months the protected structure helps to regulate the plant growth and fruit production due to improved ambient climatic conditions inside the structure. Protected cultivation created favourable environment for the plant growth which helps in obtaining early and total yield for prolonged periods. Similar findings were documented by Singh *et al* (2004). Singh *et al* (2007) also revealed that fruit yield of 6.5 kg/m<sup>2</sup> was recorded in capsicum when seedlings were transplanted in March under naturally ventilated polyhouse, whereas, there was no fruit yield when grown under open field conditions. Singh *et al* (2011) concluded that protected conditions enhanced production of sweet pepper during rainy and off-season. They recorded maximum crop duration of 270 days in polyhouse conditions, 180 days in poly tunnel as compared to 117 days in open field condition.

The year-round outdoor capsicum cultivation is restricted by biotic and abiotic stresses for early or late season cultivation. Therefore, protected cultivation provides the best way for its year-round cultivation of quality produce with high productivity.

This investigation revealed that NVPH had higher net returns varied from Rs. 65740/-, Rs. 80190/-, and Rs. 93940/- for green, red, and yellow coloured group hybrids over on an area of 500 m<sup>2</sup>. In other study Singh (2017) carried out economic analysis of capsicum under open and protected conditions reported net return of Rs. 15792/- over 500 m<sup>2</sup> area at Himachal Pradesh which is very low as compared to present investigation.

Polyhouse cultivation has emerged as a profitable and economically viable option to fetch high returns. In the present study NVPH had recorded higher benefit: cost ratio of 1.53 for green colour hybrid group and 1.61 for red colour hybrid group as compared to nethouse and walk-in-tunnel structures. However, for yellow colour group the B: C ratio was recorded as 1.75 as compared to 1.72 in NVPH. In other studies, the benefit: cost ratio for capsicum in the greenhouse was 2.98 as compared to 0.80 in case of open field condition reported by Ghosal and Das (2012). The higher Benefit: Cost ratio of 3.92 for capsicum production in protected conditions was worked out by Sreedhara *et al* (2013). Kumar *et al* (2016) recorded that higher fruit yield (145%) of capsicum in polyhouse conditions than the open field conditions. It brought 208 percent higher net returns/acre from the crop than the open field conditions. Similarly, Sharma and Kumar (2017) reported that in addition to production of better fruit quality there was increase in fruit yield to the extent of 38 per cent under low tunnel as compared to open field conditions.

Singh and Sirohi (2006) suggested that walk-in-tunnel is a low cost protected structure which is quite suitable for nursery raising and off-season year round production of vegetable for fetching higher returns of the produce. Similarly, Fatima *et al* (2017) concluded that polytunnels were more cost-effective as compared to greenhouses.

In the past some capsicum cultivars like Orobelle, Indra and Bomby were tested for cultivation in nethouse or shadenet etc. However, in the present study performance of other good cultivars for the production of different colour capsicum

for cultivation in Punjab in different types of protected structures (naturally ventilated polyhouse, Walk-in-tunnel, Nethouse etc) have been recommended. The results of present investigation revealed that the naturally ventilated polyhouse (NVPH) as proved best as compared to nethouse and walk-in-tunnel for the cultivation of green, red and yellow colour groups hybrids for commercial production. It was concluded that the capsicum hybrid namely Indra, Inspiration, and Bachata ranked first among green, red, and yellow coloured hybrids, respectively for cultivation in protected structures to gain higher net returns for polyhouse growers of Punjab State.

## CHAPTER – V

### SUMMARY

Capsicum (*Capsicum annuum* L.) belongs to the botanical family Solanaceae, is one of the highly remunerative vegetables crop cultivated in several parts of the world especially in temperate regions of Central and South America and European countries, tropical and sub-tropical regions of Asian continent. India is the second largest producers of vegetables in the world next to China with an estimated production of about 126.58 million tonnes from an area of 8.51 million hectares with an average yield of 14.87 tonnes per hectares. In Punjab it was grown on an area of 0.31 thousand hectare with annual production of 4.81 thousand MT during the year 2015-16.

In India Capsicum is grouped under non-traditional category of vegetables. Nutritionally it provides Vitamin A, C and minerals like Calcium, Magnesium, Phosphorus, Potassium, Protein, and Carbohydrates. The high market price is attributed to the heavy demand from the consumers. There is a good demand for export too.

Despite its economic importance, it is very difficult to produce good quality Capsicum with high fruit yield due to various biotic (pest and diseases) and abiotic (rainfall, temperature, relative humidity and light intensity) factors. Due to erratic weather behaviour, the crops grown under open fields are often exposed to fluctuating levels of temperature, humidity, and wind flow etc.

The cultivation of Capsicum under different protected structures like polyhouse, net house, walk-in-tunnels, plastic low tunnels are the most suitable solutions to the challenging environmental factors and it prevents spreading of insects, pests, and viral diseases, hence plays a key role in integrated pest management. Greenhouse technology can be utilized for controlling of environmental parameters such as temperature, relative humidity, light intensity & duration, CO<sub>2</sub> level, Irrigation & nutrient supply, spacing, growing medium and root development.

Now-a-days, decreasing land holdings for crop cultivation hinders the vegetable production. Hence, to obtain a good quality produce during off-season, there is a great need to cultivate Capsicum under protected conditions such as

greenhouse or polyhouse. Protected cultivation also ensures the availability of produce in the market, when it is in great demand.

There is a potential and prospects for raising *Capsicum* under protected structures to enhance crop maturity, productivity, prolonged fruiting span and high shelf life. Therefore, the study was planned with the following objectives: -

- To evaluate *Capsicum* hybrids under different protected structures.
- To study the effect and economics of different protected structures on *Capsicum* cultivation.
- To work out technology for year-round production of *Capsicum*.

The investigation entitled, 'Performance of sweet pepper (*Capsicum annuum* L.) cultivars and economics under protected structures in Punjab 'was carried out for the two consecutive cropping seasons, i.e., 2014-15 and 2015-16 under naturally ventilated polyhouse (NVPH), nethouse and walk-in-tunnel at Centre of Excellence for Vegetables (An Indo-Israel project), Kartarpur, Jalandhar, Punjab, India located at 31.44<sup>0</sup> N (latitude) and 75.5<sup>0</sup> E (longitude) at the altitude of 228 m above sea level.

The crop nursery for the two consecutive seasons was raised using black plastic pro-trays of 99 cells or cavities in polyhouse (in soilless culture media) during August 2014 and 2015, respectively. One-month old seedlings were transplanted during September 2014 (cropping season Sept 2014 to May 2015) for the first season and September 2015 (cropping season Sept 2015 to May 2016) for the second season.

The experiment was laid out in split plot design keeping naturally ventilated polyhouse, nethouse and walk-in-tunnel as main plot treatments and three different hybrids each of green coloured capsicum (Indra, Pasrella, Starlet), red coloured capsicum (Bomby, Inspiration, Mazillia) and yellow coloured capsicum (Orabelle, Bachata, Sven) as sub plot treatments with three replications each, maintaining plant to plant spacing of 40 cm and row to row spacing of 30 cm to accommodate approximately 1500 plants/500 m<sup>2</sup> area. The improved package of practices for cultivation was adopted along with improved irrigation/fertigation schedule to raise the crop.

The study the influence of different protected structures on the different colour groups of hybrids, the observations were recorded for plant height (cm), number of

branches per plant, first flower initiation (days), first fruit harvest (days), percent fruit set (%), number of fruits per plant, individual fruit weight (gm), fruit length (cm), fruit diameter (cm), fruits rind thickness (cm), fruit volume (cc), fruit shelf life (days), tolerance to major insect-pest, total fruit yield per plant (kg), total fruit yield per m<sup>2</sup> (kg), total fruit yield per hectare (tonnes), temperature (°c), relative humidity (%), light intensity (klux), and economics for two continuous seasons. The data was pooled over two seasons and subjected to statistical analysis by using software CPCS1 (Cheema and Singh, 1990).

The experimental results obtained from the present study to find the most promising hybrid for different coloured Capsicum group revealed that, with respect to vegetative growth, reproductive parameters and fruit yield related parameters like number of fruits per plant, average fruit weight, fruit yield per plant, per square metre, per hectare etc. Plants grown in NVPH had maximum plant height, fruit-set percentage, number of fruits/plants, individual fruit weight, lesser infestation of major pests, and higher total fruit yield; per plant, per square metre, and per hectare, whereas, early first flower initiation and first fruit harvest was recorded in all the three different coloured groups of Capsicum under walk-in-tunnel conditions.

Among green coloured Capsicums maximum profitability was recorded with Indra in terms of early first flower initiation (41.93 days), number of fruits/plant (21.49), total fruit yield/plant (3.62 kg) and total fruit yield/sq metre (10.86 kg) over the hybrids Pasrella and Starlet. In red coloured group, early first flowering (42.33 days), first fruit harvest (105.83 days), higher individual fruit weight (216.53 g), and total fruit yield/plant (2.81 kg) was recorded from Inspiration as compared to Bomby and Mazillia. Similarly, Bachata had earliness for first flower initiation (44.93 days), first fruit harvesting (98.19 days), and recorded maximum plant height (113.06 cm), percent fruit set (41.83), individual fruit weight (190.73 g), total fruit yield/plant (3.0 kg) over hybrids Orabelle and Sven in the yellow coloured group.

All the fruit quality parameters under study were significantly influenced by the protected structures along with their interaction effects. Among structures, NVPH cultivation recorded maximum fruit rind thickness, fruit volume and fruit shelf life, whereas, walk-in-tunnel had a great influence on fruit length and fruit diameter for all of green, red, and yellow coloured group hybrids. Green group hybrid namely Indra

had higher fruit length (9.70 cm), fruit diameter (7.50 cm), fruit shelf life (8.59) as compared to Pasrella and Starlet. The red coloured group hybrid Inspiration proved best for fruit length (9.70 cm), fruit diameter (8.23 cm), fruit volume (434 cc), fruit rind thickness (0.89 cm), and fruit shelf life (8.0 days) as compared to Bomby and Mazillia. The yellow coloured group hybrid Bachata recorded maximum fruit length (9.03 cm), fruit volume (388.66 cm), and fruit rind thickness (0.90 cm) as compared to Orobelle and Sven.

When the environmental temperature fell down in the winter months, the protected structures helped to regulate the plant growth and production characters due to improved ambient/micro climatic conditions inside the structure. Protected cultivation created favourable environment for the plant growth which helped getting early and total fruit yields for an extended period.

NVPH unit were established over an area of 2000 m<sup>2</sup>. For calculating the economics of capsicum cultivation, the fixed and variable costs for the establishment and maintenance of structures for 500 m<sup>2</sup> area were calculated from the total costs of 2000 m<sup>2</sup>. The results revealed that among green group hybrids, Indra had higher net returns of Rs. 65740/- from NVPH which resulted in highest B:C ratio of 1:1.53. Among red group hybrids, Inspiration had higher net returns of Rs. 80190/- from NVPH with highest B:C ratio of 1:1.61. Among the yellow coloured group hybrids, Bachata gained maximum net returns of Rs. 93940/- from NVPH. However, Bachata also gained maximum B:C ratio of 1:1.75 from walk-in-tunnel followed by NVPH having B:C ratio of 1:1.72.

In the present study plant spacings kept as 40 x 30 cm between rows and plants, respectively which was sufficient for proper utilization of land and space over a unit of area for fetching high returns. Maximum fruit yield under protected conditions was the result of increased plant height, fruit length, fruit weight and fruit girth, longer fruiting span etc. It was gained might be due to the high rate of carbon dioxide utilization in the polyhouse. Similarly, Singh *et al* (2011) and Basavaraja *et al* (2003) reported that the higher fruit yield in polyhouse, polytunnel may be due to the improved climate in these conditions. They concluded that the temperature range was

found 3-4<sup>0</sup>C higher in polyhouse, and 1-2<sup>0</sup>C higher in polytunnel as compared to unprotected cultivation conditions.

It is opined that due to favourable environmental conditions prevailing in polyhouse which helped in gaining better plant growth of roots and shoots, improved the fruit yield attributing parametres like number of fruits per plant, individual fruit weight, fruit rind thickness, fruit length and fruit breadth which led to higher total yield per plant and per square metre/hectare. Protected cultivation of capsicum is the best practice to grow off-season crop to meet the consumer's demand and daily nutritional requirements. Polyhouse cultivation has thus emerged as a profitable and economically viable option to fetch high returns especially in off-seasons in Punjab.

The present investigation results, therefore, suggest that the naturally ventilated polyhouse (NVPH) was the best as compared to nethouse and walk-in-tunnel for the cultivation of green, red and yellow coloured group hybrids of capsicum for commercial production in Punjab. It is further concluded that Indra, Inspiration, and Bachata hybrids of capsicum ranked first among green, red, and yellow coloured groups respectively for commercial cultivation under protected structures to gain higher net returns per unit area for Punjab conditions.



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