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Growth, yield and economics of greenhouse grown coloured capsicum as influenced by trellis system and plant spacing

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ABSTRACT

The experiment was laid out in split plot design and the treatments comprised V trellis with two stems (T_1), V trellis with four stems (T_2) and Spanish trellis (T_3) as main plot along with three plant spacing levels, viz. S_1 (40 cm × 40 cm), S_2 (60 cm × 40 cm) and S_3 (60 cm × 60 cm) as sub plot treatments. Results of the study showed that plant height was significantly affected by trellis, spacing and their interactions. Number of fruits/plant was highest under Spanish trellis and wider spacing (S_3). Fruit weight, yield/plant and yield/square meter were observed to be significantly higher under V trellis with two and four stems as compared to Spanish trellis. Plant spacing also influenced these parameters significantly and although fruit weight and yield/plant were higher in wider spacing treatment (S_3), yield per square meter was significantly higher in close spacing (S_1). Economic analysis indicated that V trellis with four stems at 40 cm×40 cm spacing is optimum for more income per rupee invested for greenhouse cultivation of coloured capsicum.

Key words: Benefit cost ratio, Capsicum, Fruit weight, Spacing, Trellis, Yield per plant, Yield per square meter

Capsicum is one of the most important nutritious and highly remunerative vegetable crops grown for its fruits. Nowadays, different coloured hybrids are available but yellow and red fetch higher price in the market. It is not possible to obtain higher yields of good quality fruits (green or coloured) under open conditions and therefore protected cultivation offers good scope for year round and also off season production of coloured capsicum. In protected cultivation, pruning and plant density are very important for optimization of plant number per unit area. Plant density and arrangement have a pronounced influence on development, growth and marketable yield of many vegetable crops. Trellising/pruning the plants facilitate easy operations and also permit closer planting and get higher yields of larger sized fruits. The need for having appropriate plant densities in order to boost-up the production per unit area by utilizing the available space and nutrient applied is also very important in protected cultivation.

There are many studies on plant density for different types of pepper (Cebula 1995, Jolliffe and Gaye 1995). Plant density and arrangement have a pronounced influence on plant development, growth and marketable yield of many vegetable crops (Stoffela and Bryan 1988). A number of studies have indicated a linear increase in fruit yield when plant density is increased (Motsenbocker 1996, Stoffela and Bryan 1988, Decoteau and Graham 1994) and the increase in yield with higher plant density was a result of increased number of fruits per unit area. Although, some information on plant density of capsicum in open field condition is available, studies on greenhouse production are limited. The optimization of plant and shoot spacing in greenhouse production of bell pepper was investigated by Cebula (1995), plants were trained to two shoots and the spacing of plants was 80 cm × 30 cm. As the area under protected cultivation is growing at considerable pace, farmers are still groping in dark about the proper training/ pruning practice for getting maximum benefits under greenhouses. The present study was therefore carried out to determine the optimum plant density and trellis system for capsicum grown in greenhouses.

MATERIALS AND METHODS

The studies were carried out in the polyhouse at the Experimental Farm, Department of Soil Science and Water Management, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh. The farm lies at 30°50'30" N latitude and 77°08'30"E longitude and located at an elevation of 1150 m AMSL. The growing media was prepared by mixing farmyard manure in the soil @ 50 kg/ m^2 and exhibited slightly acidic reaction, low salt

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Table 1 Characteristics of the soil before the start of the experiment

Soil characteristics	Contents
pH	6.65
Electrical conductivity (dS/m)	0.22
Organic carbon (g/kg)	23.1
Available N (kg/ha)	366
Available P (kg/ha)	36
Available K (kg/ha)	260

concentration, high organic carbon, available phosphorus and potassium and medium available nitrogen status (Table 1).

The study site was prepared in 3.8 m long and 1.0 m wide beds raised to 40 cm and surface drip irrigation system was installed. The capsicum variety Orobelle was transplanted at six leaf stage and standard practices of fertilization and irrigation for capsicum production in polyhouses were followed.

The experiments were laid out in split plot design with three main plot and three subplot treatments replicated four times as per details given below:

Main plot treatments = 3

T_1 - V trellis with two stems

T_2 - V trellis with four stems

T_3 - Spanish trellis

Sub plot treatments = 3

S_1 = 40 cm × 40 cm (6.2 plants/m^2)

S_2 = 60 cm × 40 cm (4.2 plants/m^2)

S_3 = 60 cm × 60 cm (2.8 plants/m^2)

Replications = 4

For the determination of plant height, four plants were tagged at random in each treatment and were measured from the ground level to the growing tip of the main stem at 150 days after transplanting. The average height was calculated and expressed in centimeters. The number of set fruits from tagged plants was recorded during the experiment and the total and average were calculated at the end of experiment. For yield parameters, the fresh weight of capsicum fruits harvested from the labeled plants from each treatment were weighed and recorded in grams. The weight of matured fruits harvested from each picking was recorded till final harvest and total yield of fruits per plant was computed in kilograms. The number of fruits harvested per plant in different pickings was summed up. For calculation of yield per square meter, the yield per plant was multiplied by respective number of plants in unit area under different treatments. After taking into consideration the fixed (Structure erection, irrigation system etc.) and variable inputs (planting material, plant protection and labour etc.), the expenditure incurred was worked out for each treatment. The average selling price of capsicum was ₹ 50/ kg and gross returns were calculated on the basis of this price. Benefit-cost ratio was worked out for different treatments.

RESULTS AND DISCUSSION

Plant height of capsicum differed significantly due to training levels, spacing and their interactions (Table 2). Maximum height (147.6 cm) was recorded under V trellis with four stems, which may be due to the competition for sunlight among the shoots. Among the spacing, closer spacing (S_1) resulted in getting maximum (146.7 cm) plant height which was statistically at par with S_2, but significantly higher than S_3. This might be due to enhanced competition for space and light, thereby forcing the plants to grow taller. The short and stout plants under wider spacing may be due to availability of more growing space and thus the plants were able to exploit more nutrients from the soil and also the light sources. Among the interactions, T_2S_1 recorded maximum (154.6 cm) plant height, being at par with T_1S_1 (150.1cm) and was statistically higher than all other treatment combinations. This is in agreement with the previous studies conducted by Shabnum *et al.* (2004), who also reported gradual reduction in plant height in wider spacing.

Although, number of fruits/plant were observed to be highest under T_3 (27.1) but trellis treatment failed to impart significant effect on the parameter. Among the spacing, wider spacing (S_3) recorded highest number of fruits (28.1) which was significantly higher than S_1 (21.2).

Trellis and spacing combination T_3S_3 recorded highest number of fruits/plant being statistically at par with T_3S_2 and T_2S_3 and was significantly higher than all other treatment combinations. This was due to the fact that wider spacing

Table 2 Plant height and number of fruits/plant as influenced by trellis and spacing treatments

Spacing	Plant height (cm)				Number of fruits/plant				Unmarketable fruits/plant			
	Trellis				Trellis				Trellis			
	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean
S_1 40 cm × 40 cm	150.1	154.6	135.4	146.7	21.7	19.9	22.2	21.2	1.95	2.30	3.68	2.64
S_2 60 cm × 40 cm	141.9	149.5	131.8	141.0	24.7	26.9	28.5	26.7	1.85	2.18	3.45	2.49
S_3 60 cm × 60 cm	134.0	138.8	135.3	136.0	25.7	28.1	30.5	28.1	1.75	1.98	3.43	2.38
Mean	142.0	147.6	134.2		24.0	24.9	27.1		1.85	2.15	3.52	
	$CD_{0.05}$ Trellis = 14.6				$CD_{0.05}$ Trellis = NS				$CD_{0.05}$ Trellis = 0.37			
	$CD_{0.05}$ Spacing = 10.1				$CD_{0.05}$ Spacing = 2.5				$CD_{0.05}$ Spacing = NS			
	$CD_{0.05}$Trellis × Spacing= 11.3				$CD_{0.05}$Trellis × Spacing = 2.7				$CD_{0.05}$Trellis × Spacing = NS			

Table 3 Effect of trellis and spacing on fruit weight, marketable yield/plant and marketable yield/ m^2

Spacing	Fruit weight (g)				Marketable yield/plant (kg)				Marketable yield/m^2 (kg/m^2)			
	Trellis				Trellis				Trellis			
	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean
S_1 40 cm × 40 cm	178.0	169.4	165.5	171.0	5.71	5.95	4.85	5.50	35.66	37.18	30.31	34.38
S_2 60 cm × 40 cm	228.4	220.3	185.3	211.3	6.54	7.87	6.09	6.83	26.18	31.47	24.37	27.34
S_3 60 cm × 60 cm	249.2	230.1	190.8	223.3	7.64	8.21	6.64	7.50	21.40	22.99	18.61	21.00
Mean	218.5	206.6	180.6		6.63	7.34	5.86		27.75	30.55	24.43	
	$CD_{0.05}$ Trellis = 28.9				$CD_{0.05}$ Trellis = 1.03				$CD_{0.05}$ Trellis = 4.90			
	$CD_{0.05}$ Spacing = 19.8				$CD_{0.05}$ Spacing = 0.61				$CD_{0.05}$ Spacing = 3.0			
	$CD_{0.05}$ Trellis×Spacing = 22.1				$CD_{0.05}$ Trellis × Spacing = 0.68				$CD_{0.05}$ Trellis × Spacing = 3.35			

and no or less training of shoots resulted in more number of main stems and consequently more flowering nodes and fruits as compared to heavy training and closer spacing in other treatment combinations. Similar results were also reported by Dasgan and Abak (2003). Unmarketable fruits were mainly misshapen and flat fruits. Spanish trellis recorded significantly higher misshapen fruits (3.30), whereas V trellis with two stems recorded lowest values (Table 2). Misshapen fruits were generally observed when the fruits were developing between the stems, resulting in fruits not receiving space for growth. In V trellis, the plants were properly trained and therefore very less misshapen fruits were observed, whereas irregular plant structure in Spanish trellis resulted in more number of such fruits. Maboko *et al.* (2012) also reported that deformed fruits in hydroponically grown pepper were generally observed when the fruits were developing between the stems and not receiving room for growth.

Data pertaining to fruit weight presented in Table 3 suggest that the pruning treatment resulted in maximum fruit weight as compared to unpruned plants, V trellis with two stems registered highest (218.5 g) which was significantly higher than T_3 (180.6 g). This may be due to adequate supply of metabolites to the limited number of fruits under V trellis system. The results are in accordance with observations by Joshi *et al.* (1992) in tomato. Among the spacing treatments, highest fruit weight was observed under S_3, being statistically at par with S_2 and significantly higher than S_1 which might be due to increased uptake of nutrients due to wider spacing and thus build up of sufficient photosynthates enabling the increase in the fruit weight. Among the interactions, treatment combination T_1S_3 recorded highest fruit weight (249.2 g), whereas lowest was registered under T_3S_1 (165.5 g), which may be due to positive interaction of trellis and spacing and additive effects of mentioned factors as better nutrient uptake under wider spacing and distribution of metabolites to the fruits. Islam *et al.* (2011) have also reported maximum fruit weight in widest spacing. The results are in agreement with Verheij and Verwer (1971) who reported that the individual fruit weight declined with increased plant density.

Trellis system influenced the marketable yield/plant and per square meter significantly (Table 3) and highest was observed under T_2 (7.34 kg/ plant and 30.55 kg/m^2, respectively), whereas, Spanish trellis (T_3) recorded lowest values (5.86 kg/plant and 24.43 kg/m^2). Spacing treatment imparted significant effect on yield/plant and highest was registered under S_3 (7.50 kg/plant) and lowest under S_1 (5.50 kg/plant). Due to more number of plants per unit area in closer spacing, vice versa was observed for yield per square meter and highest was recorded under S_1 (34.38 kg/m^2), which was significantly higher than S_3 (21.00 kg/m^2).

Interactions between trellis and spacing produced significant effect on marketable yield per plant and T_2S_3 recorded the highest (8.21 kg/ plant), whereas lowest (4.85 kg/ plant) was found under the treatment combination T_3S_1. Similarly interactions between trellis and spacing imparted significant effect on yield per square meter and significantly higher values were observed under T_2S_1 (37.18 kg/m^2) and T_1S_1 (35.66 kg/m^2) treatment combinations. It might be due to the fact that although number of fruits was higher in Spanish trellis, fruit weight was significantly lower as compared to V trellis. Higher incidence of diseases (powdery mildew, root rot etc.) and more number of misshapen fruits also rendered some fruits unfit for the market and thus result in lower marketable yield. In V trellis system, timely and systematic pruning of shoots resulted in well structured plants having higher fruit weight, very less or no misshapen fruits and thus produced higher marketable yield. In case of

Table 4 Benefit cost ratio (Rupees) under different trellis and spacing treatments

	T_1		T_2		T_3	
Cost of cultivation (₹)	S_1	47505	S_1	49305	S_1	43905
	S_2	45035	S_2	46835	S_2	41435
	S_3	43725	S_3	45525	S_3	40125
Net return (₹)						
	S_1	219252	S_1	228764	S_1	182802
	S_2	151293	S_2	189209	S_2	141312
	S_3	116793	S_3	126928	S_3	99418
Benefit cost ratio						
	S_1	4.62	S_1	4.64	S_1	4.16
	S_2	3.36	S_2	4.04	S_2	3.41
	S_3	2.67	S_3	2.79	S_3	2.48

spacing treatments, wider spacing (S_3) produced higher yield per plant but as number of plants per square meter are less, therefore, per square meter yield was highest under closer spacing treatment (S_1). Dasgan and Abak (2003) also obtained maximum yield under wider spacing (80 cm × 56 cm) with four shoots. Jovicich *et al.* (2004) also observed maximum yield when 3.8 plants per m^2 were pruned to four stems.

Benefit-cost ratio

The economic analysis (Table 4) indicate that cost of cultivation varied with trellis and spacing. Net return was recorded to be highest under T_2S_1, whereas minimum was observed under T_3S_3. V trellis with two and four stems was economically beneficial (B:C ratio of 4.62 and 4.64, respectively) for capsicum in terms of net seasonal income. It can also be observed that as spacing increased, benefit cost ratio declined under all the treatments due to reduction in number of fruits per unit area.

Hence, it can be concluded from the study that, for better returns in capsicum cultivation under protected cultivation, the plants should be maintained under V trellis with four stems and spacing should be kept as 40 cm × 40 cm, i e 6.2 plants/m^2. The areas where humidity is very high and due to this, the incidence of diseases is common, for better economics, V trellis with two stems may be adopted as it facilitates better aeration and sunlight interception and thus helps to reduce disease incidence.

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