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Impact of spacing and training on seed yield of capsicum, *Capsicum annuum* L under protected conditions

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ABSTRACT

The study was conducted during Kharif 2012 to find out optimum planting density and training system for seed production of bell pepper, *Capsicum annuum* L under protected conditions using cultivar Solan Bharpur. The treatment combinations comprised of three planting densities (S) viz S_1 (45 x 15 cm), S_2 (45 x 30 cm) and S_3 (45 x 45 cm) and four training levels (T) viz T_1 (single shoot), T_2 (two shoots), T_3 (three shoots) and T_4 (four shoots). The observations were recorded in the field on plant height (cm), days to ripe fruit harvest, ripe fruit weight (g), number of ripe fruits/plant, ripe fruit yield/plant (kg), number of seeds/fruit, per cent seed recovery, seed yield/plant (g), seed yield/m^2 (g) and seed yield/ha (kg). Analysis of variance showed that the combination S_2T_2 (plants spaced at 45 x 30 cm and trained to two shoots) was found superior over all other treatments in terms of economic characters such as total fruit yield/plant and seed yield (per plant, per m^2 and per hectare).

Keywords: Planting density; training system; bell pepper; seed yield

INTRODUCTION

The bell pepper, *Capsicum annuum* L is an important off-season cash crop amongst the solanceous vegetables cultivated in Himachal Pradesh, UP, parts of Gujarat, Uttarakhand, Jammu and Kashmir, parts of West Bengal, Maharashtra and Karnataka states of India (Chadha 2005). Bell pepper is a cool season tropical crop and lacks adaptability to varied environmental conditions (Yoon et al 1989). There is great diversity of climate in India and agro-climatic conditions of the plains are not conducive for seed production of bell pepper due to various biotic (pests and diseases), abiotic (rainfall, temperature, relative humidity and light intensity) and crop factors (flower and fruit drop).

Greenhouse the latest word in Indian agriculture is one such means where the plants are grown under controlled or partially controlled environment resulting in higher yields than that is possible under open conditions (Navale et al 2003). The growers can cultivate a crop in any season under protected environment.

Growing plants in polyhouse improves the quality of fruit which ultimately improves quality of seeds and in turn helps the farmers to fetch the good price.

In greenhouse cultivation main emphasis is given on appropriate cultural practices such as plant densities and training systems in order to enhance the production per unit area by utilizing the available space and utilization of the resources. An appropriate training system will not only facilitate better management and uniform light to the plants but also permit closer planting, early ripening of fruits, higher yield of larger sized fruits and higher yield of good quality seeds. Training systems vary with different growth habits and plant densities. In India or other countries the use of agro-techniques like appropriate planting density and training of plants has been carried out for fresh vegetable production but the use of these agro-techniques has not been done yet on large scale for the seed production under the protected conditions. The growth, yield and quality attributes of capsicum are profoundly influenced by the cultural practices like proper plant spacing and training level. Keeping in view the above facts the present investigations were planned to identify the suitable planting density and training system for bell pepper seed production under protected conditions.

MATERIAL and METHODS

The present investigations were carried out in the Department of Seed Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan during Kharif 2012 in bell pepper cv Solan Bharpur. The experiment was laid in randomized block design (factorial). The seedlings were transplanted at different spacings (S) viz S_1 (45 x 15 cm), S_2 (45 x 30 cm) and S_3 (45 x 45 cm) in a plot having size of 2 x 0.9 m ie 1.8 m^2 in naturally ventilated (top and side ventilated) polyhouse and after establishment of seedlings they were trained to four training levels (T) viz T_1 (single shoot), T_2 (two shoots), T_3 (three shoots) and T_4 (four shoots) replicated four times. The observations were recorded on five randomly selected plants from each replication for all characters under study.

The characters studied were:

Growth characters: Plant height was recorded from the soil level to the tip of the plant at the end of the crop season ie at the start of leaf senescence and mean height was expressed in centimeters. Number of days to ripe fruit harvest was counted from the date of transplanting to fully developed red ripe fruits and mean was worked out.

Fruit yield characters: The ripe fruit weight was calculated by weighing ten

red ripe fruits of second harvest and their average was worked in grams. The number of fruits from each picking was counted and cumulative total after last picking was expressed as number of fruits per plant. Weight of ripe fruits harvested was taken and averaged to work out the fruit yield per plant in kg.

Seed yield characters: Total number of seeds was counted from randomly selected ten fruits at second harvest and average value was worked out to calculate number of seeds per fruit in each treatment combination. One kilogram ripe fruits from each plot were taken and their seeds were extracted and dried. The seed recovery percentage was calculated as:

$$\text{Seed recovery (\%)} = \frac{\text{Total seed weight extracted from ripe fruits (g)}}{\text{Total fruit weight (g)}} \times 100$$

The harvested seeds were dried to 8 per cent moisture content, weighed and averaged to work out seed yield per plant, seed yield/m^2 and seed yield/ha. While calculating the seed yield per hectare twenty per cent area was considered as depreciation for construction of channels in the polyhouse.

The statistical analysis was done as per design of the experiment as suggested by Gomez and Gomez (1984).

RESULTS and DISCUSSION

The interaction effects revealed that S_3T_1 (45 x 45 cm and single shoot) resulted in the highest plant height (161.35 cm) and minimum days to ripe fruit harvest (94.92) (Table 1). This may be due to enhanced apical dominance and low competition for the nutrients and aerial space within or between the plants and wider spacing in combination with low shoot density resulting in early maturation of fruit as there was less competition for the light and nutrient among the plants. These results are in agreement with Aminifard et al (2012) who also reported the maximum plant height at wider plant spacing in capsicum. Aktas et al (2009) also concluded that the single branch pruning increased the height of plant. Kishor (2012) reported minimum number of days to ripe fruit harvest at wider spacing. Similarly highest ripe fruit weight (67.18 g) was obtained from S_3T_1 (Table 1). This could be because at the wider spacing and low shoot density the competition for the nutrient and light among the plants and within the plant was low as compared to that of high plant and shoot density. Aminifard et al (2012) reported that fruit weight decreased with increasing plant population in capsicum. The contrasting results were obtained by Jovicich et al (1998) who indicated that extra large fruit yield/plant was greatest in four stem plants. S_2T_4 (45 x 30 cm and four shoots) recorded

Table 1 Effect of planting density and training on growth and fruit yield characters in seed production of bell pepper cv Solan Bharpur under protected conditions

Growth character	Treatment				
	T_1	T_2	T_3	T_4	Mean (S)
Plant height (cm)					
S_1	147.40	142.48	135.83	128.40	138.53
S_2	156.00	144.65	138.03	135.70	143.59
S_3	161.35	154.65	144.30	138.28	149.65
Mean (T)	154.92	147.26	139.38	134.13	
$CD_{0.05}$ (T): 2.22, $CD_{0.05}$ (S): 1.92, $CD_{0.05}$ (TxS): 3.84					
# Days to ripe fruit harvest					
S_1	104.99	105.58	107.34	109.22	106.78
S_2	99.15	100.16	102.37	105.29	101.74
S_3	94.92	97.49	100.32	103.59	99.08
Mean (T)	99.69	101.08	103.34	106.03	
$CD_{0.05}$ (T): 1.92, $CD_{0.05}$ (S): 1.66, $CD_{0.05}$ (TxS): 3.33					
Ripe fruit weight (g)					
S_1	56.55	53.78	49.21	46.75	51.57
S_2	62.30	62.43	57.44	53.44	58.90
S_3	67.18	63.05	58.55	55.05	60.96
Mean (T)	62.01	59.75	55.07	51.75	
$CD_{0.05}$ (T): 1.94, $CD_{0.05}$ (S): 1.68, $CD_{0.05}$ (TxS): 3.36					
# Ripe fruits/plant					
S_1	8.25	9.50	10.00	10.00	9.44
S_2	13.00	15.25	15.25	15.50	14.75
S_3	9.50	10.75	13.50	14.25	12.00
Mean (T)	10.25	11.83	12.92	13.25	
$CD_{0.05}$ (T): 0.76, $CD_{0.05}$ (S): 0.65, $CD_{0.05}$ (TxS): 1.31					
Ripe fruit yield/plant (kg)					
S_1	0.47	0.51	0.49	0.47	0.48
S_2	0.81	0.95	0.88	0.83	0.87
S_3	0.64	0.68	0.79	0.82	0.73
Mean (T)	0.64	0.71	0.72	0.70	
$CD_{0.05}$ (T): 0.05, $CD_{0.05}$ (S): 0.04, $CD_{0.05}$ (TxS): 0.08					

Table 2. Effect of planting density and training on seed yield characters in seed production of bell pepper cv Solan Bharpur under protected conditions

Character	Treatment				
	T_1	T_2	T_3	T_4	Mean (S)
			Growth character		
# Seeds/fruit					
S_1	167.20	162.10	156.63	152.11	159.51
S_2	193.52	189.73	187.18	182.37	188.20
S_3	198.14	193.90	190.88	186.64	192.39
Mean (T)	186.29	181.91	178.23	173.71	
$CD_{0.05}$ (T): 1.00, $CD_{0.05}$ (S): 0.86, $CD_{0.05}$ (T x S): 1.73					
Per cent seed recovery					
S_1	1.62 (1.62)	1.59 (1.61)	1.65 (1.63)	1.64 (1.62)	1.62 (1.62)
S_2	1.91 (1.71)	1.89 (1.70)	1.91 (1.71)	1.89 (1.70)	1.90 (1.70)
S_3	1.86 (1.69)	1.94 (1.71)	1.98 (1.73)	1.96 (1.72)	1.93 (1.71)
Mean (T)	1.80 (1.67)	1.81 (1.67)	1.85 (1.69)	1.83 (1.68)	
$CD_{0.05}$ (T): NS, $CD_{0.05}$ (S): 0.02, $CD_{0.05}$ (T x S): NS					
			Fruit yield character		
Seed yield/plant (g)					
S_1	7.55	8.09	8.10	7.62	7.84
S_2	15.47	18.00	16.74	15.63	16.46
S_3	11.89	13.08	15.59	15.93	14.12
Mean (T)	11.64	13.05	13.48	13.06	
$CD_{0.05}$ (T): 0.79, $CD_{0.05}$ (S): 0.68, $CD_{0.05}$ (T x S): 1.36					
Seed yield/m² (g)					
S_1	100.70	107.80	107.94	101.66	104.53
S_2	103.17	119.98	111.62	104.18	109.74
S_3	52.83	58.13	69.28	70.78	62.75
Mean (T)	85.57	95.30	96.28	92.20	
$CD_{0.05}$ (T): 5.96, $CD_{0.05}$ (S): 5.17, $CD_{0.05}$ (T x S): 10.33					
Seed yield/ha (kg)					
S_1	805.62	862.40	863.51	813.24	836.19
S_2	825.35	959.87	892.96	833.39	877.89
S_3	422.62	465.04	554.21	566.19	502.01
Mean (T)	684.53	762.44	770.22	737.61	
$CD_{0.05}$ (T): 47.71, $CD_{0.05}$ (S): 41.32, $CD_{0.05}$ (T x S): 82.64					

Figures in the parentheses represent square root transformation

higher number of fruits per plant (15.50) (Table 1). This might be due to congenial climate coupled with optimum plant spacing and training level. Similar observations were recorded by Cebula et al (1995) and Dasgan and Abak (2003) in bell pepper. The combination S_2T_2 (45 x 30 cm and two shoots) gave the highest ripe fruit yield per plant (0.95 kg) (Table 1). Cebula et al (1995) suggested that at higher plant density plant efficiency would be increased by higher LAI and a high net assimilation rate in bell pepper resulting in higher biomass and fruit yield. Jovicich et al (1998) also observed the similar results when four plants per m^2 were pruned to four stems in sweet pepper.

Maximum number of seeds per fruit (198.14) was obtained with the combination S_3T_1 (Table 2). This might be due to the reason that wider spaced and single shoot plants bore larger sized fruits while closer spaced and dense shoots per plant resulted in small sized fruits and size of fruit is correlated to number of seeds (Kinet and Peet 1997). Effect of treatment combinations on per cent seed recovery was found to be non-significant. The seed yield was significantly affected by the treatment combination S_2T_2 (45 x 30 cm and two shoots) that gave the highest seed yield per plant, seed yield per m^2 and per hectare (18.00 g, 119.98 g and 959.87 kg, respectively) (Table 2) which might be due to optimum plant density and appropriate level of training required for growth and development of the plant and finally higher seed yield. Patil and Singh (1979) in chilli and Sanchez et al (1993) reported that closer spacing resulted in lower seed yield per plant in bell pepper. Patil and Singh (1979), Lal (1992), Singh et al (1989) and Khurana et al (2002) also reported that wider spacing resulted in lower seed yield per m^2 and per hectare in chilli. Another reason might be the extended cropping season. In the field bell pepper can be harvested over a period of 2-3 months but in greenhouse production season can be extended for 8 months (Wien 1997).

From the present study it can be concluded that the combination S_2T_2 (plants spaced at 45 x 30 cm and trained to two shoots) was found superior over all other treatments in terms of economic character such as total fruit yield/plant and seed yield (per plant, per m^2 and per hectare) which is an ultimate goal of any experiment. Therefore planting density S_2 (45 x 30 cm) in combination with training system T_2 (two shoots) can be recommended for commercial cultivation after multilocation testing for getting the higher yield of quality seeds in bell pepper under protected conditions in Himachal Pradesh.

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