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Effect of spacing and nitrogen level on growth and yield of bell pepper (*Capsicum annuum* L.) under dry temperate climate of western Himalayas

A. KUMAR AND [1]S. S. RANA

Highland Agricultural Research and Extension Centre, CSK HPKV, Kukumseri, Himachal Pradesh, India 175142, [1]Department of Agronomy, Forages and Grassland Management, CSK HPKV, Palampur, India-176062

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ABSTRACT

To find out optimum crop geometry and nitrogen in bell pepper under high altitude dry temperate climate of western Himalayas, three levels of nitrogen (N_1-100, N_2-125 and N_3-150 kg N.ha^{-1}) and two of spacing (S_1-45 × 45 cm and S_2-60 × 45 cm) were evaluated at Kukumseri during the summer seasons of 2011 and 2012. Higher number of branches per plant was obtained at 60 × 45 cm (S_2). The crop took 3 and 4 days more to flowering and fruiting at wider spacing of 60 × 45 cm (S_2). Fruit length (4.67 cm), fruit width (4.50 cm), fruits plant^{-1} (8.51), fruit weight (28.21 g) and fruit weight plant^{-1} (212.77g) were higher at 60 × 45 cm (S_2) spacing. The total yield was significantly higher at closer spacing of 45 × 45 cm (S_1) during 2012 only. However during 2011 and averaged over years the yield did not differ significantly between crop geometry of 45 × 45 cm (S_1) and 60 × 45 cm (S_2). Net returns were Indian Net Rupees (INR) 4487 more with 60 × 45 cm (S_2) crop geometry compared to 45 × 45 cm (S_1). B:C was also higher under wider spacing than closer spacing. Increasing level of nitrogen from recommended to 150 per cent of recommended significantly increased the number of days taken to 50% flowering and fruiting. Fruit length (4.63 cm), fruit width (4.62 cm), number of fruits plant^{-1} (9.05), fruit weight (28.71g), fruit weight plant^{-1} (215.53 g) were highest at 150% of recommended N (N_3) followed by 125% N (N_2). The net returns increased by rupee 31,154 and rupee 14,889 with application of 150 (N_3) and 125% N (N_2), respectively over present recommended N application (N_1-100 kg N, 60 kg each of P_2O_5 and K_2O). B:C also increased with increase in N dose.

Keywords **:** Bell pepper, economics, nitrogen, reproductive parameters, spacing

Bell pepper occupies an important position as a commercial crop in India. It is a most important polyhouse crop along with tomato in almost all regions of India. Its open field cultivation in region specific season is also widespread. In Himachal Pradesh, it has emerged as the most popular polyhouse crop (Rana *et al*., 2015) with open field cultivation restricted to some areas. Capsicum being cool season crop, sensitive to high rainfall and requires day and night temperature between 26-28 °C and 14-16 °C, respectively. The Lahaul Valley in Western Himalayas has dry temperate climate with rainfall below 150 cm in the main summer season can be a ideal place for cultivation of cool climate loving crops. In valley cole crops, peas and potato are widely cultivated as off season crop but cultivation of tomato and capsicum is not popular. With promotion of tourism and outreach of people the demand for other crops like tomato and capsicum in this tribal belt has increased. Although capsicum cultivation in polyhouse is coming up slowly but its cultivation in open field has not been taken yet due to lack of information. Like other vegetables of the region it will be another off season vegetable. To get the higher productivity, standardization of optimum spacing and suitable level of fertilizer is necessary [Khasmakhi-Sabet *et al*., 2009; Aminifard *et al.,* 2012]. Studies on the spacing requirements, plant population and density are extensive on sweet pepper varieties [Bosland 2000; Mavengahama *et al.,* 2009; Alabi *et al.*, 2014]. Nitrogen is the most important nutrient restricting the yield [Bhuvaneswari *et al.,* 2014; Aminifard *et al.,* 2012] especially in regions where it is deficient or in medium range. Therefore, an experiment was conducted to find out the effect of spacing and different levels of nitrogen on growth and yield of bell pepper under open field conditions of dry temperate conditions.

MATERIALS AND METHODS

Field experiment was conducted at the Research Farm of Highland Agricultural Research and Extension Centre, Chaudhary Sarvan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Kukumseri (32º 442 552 2 N latitude and 76 º 41’23’’ E longitudes), India during the summer seasons of 2011 and 2012. The climate of the region was described by moderate summers and cool winters. Kukumseri is falling in falling in Lahaul valley which is situated in rain shadow area, north of the Pir Panjal ranges. The weather remains pleasant and quite comfortable during summers *i.e*. from May to mid October. It seldom rains, and the Mercury level does not exceed 30 °C and never falls below 15 °C through out summers. There is little or no rain in monsoons. The climate remains dry and invigorating. The days are hot and nights are extremely cold. During winter, *i.e*. from

Email: anil.an69@rediffmail.com

November last to April because of western disturbances it snows heavily and the temperature goes down below minus. There is an average annual snow fall of about 2 m. The soil of experimental site was sandy loam, having pH 6.6, organic carbon 6.46 g kg^{-1} soil, available nitrogen 264.4 kg ha^{-1}, phosphorus 18.3 kg ha^{-1} and potassium 152.1 kg ha^{-1}.

The experiment was laid out in split plot design with two spacing (S_1-45 × 45 cm and S_2-60 × 45 cm) in main plot and three levels of nitrogen (N_1-100, N_2-125 and N_3-150 kg N ha^{-1}) in sub plot with four replications.

The 3-4 leaf healthy seedling of variety 'California Wonder' raised in poly house were transplanted in field after hardening period outside polyhouse of two days. The transplanting was done on June 2, 2011 and May 28, 2012. The half of nitrogen as per treatment and full P_2O_5 (60 kg ha^{-1}) and K_2O (60 kg ha^{-1}) were applied at the time of transplanting. The remaining nitrogen was applied in two splits of 1/4 at 30 DAT (days after transplanting) and 1/4 nitrogen at time of flowering. The nitrogen, phosphorus and potash were applied through urea, single super phosphate and muriate of potash, respectively. The crop was irrigated twice a week depending upon the demand. The herbicide was applied with manually operated knapsack sprayer using a spray volume of 500 litres of water per hectare. The observations on growth, time to attain different phonological stages, yield and yield attributes were calculated as per standard procedure. The crop was harvested in four lots from a net plot of 3.6 x 3.15 m. The economics was calculated based on the prevailing market prices. Net returns were obtained by subtracting total cost of cultivation from gross returns. B:C was obtained by dividing gross returns with cost of cultivation.

The data obtained were subjected to statistical analysis by analysis of variance (ANOVA) for the split plot design to test the significance of the overall differences among the treatments by the "F" test and conclusion was drawn at 5per cent probability level. Standard error of mean was calculated in each case. When the 'F' value from analysis of variance tables was found significant, the critical difference (LSD) was computed to test the significance of the difference between the two treatments.

RESULTS AND DISCUSSION

Effect of spacing

Significant effect of crop geometry was observed on growth, phenology, yield and yield attributes (Table 1 and 2). Higher number of branches plant^{-1} was obtained under S_2 [60 × 45 cm] compared to S_1 [45× 45 cm] spacing. This may be attributed to better space and root spread with wider spacing resulting in better light and nutrients utilization. The crop took 3 and 4 days more to flowering and fruiting at wider spacing of 60 × 45 cm. Pundir and Porwal (1999) also reported delay in flowering at wider spacing. The better nutrient feeding zone at wider spacing might have enhanced the vegetative phase hence delay can be expected. The yield attributes *viz*. fruit length (4.67 cm), fruit width (4.50 cm), number of fruits plant^{-1} (8.51), fruit weight (28.21 g) and fruit weight plant^{-1} (212.77g) were higher at S_2 [60 x 45 cm] spacing compared to S_1 [45 × 45 cm]. Bosland (2000), Mavengahama *et al.* (2009) and Alabi *et al.* (2014) also reported the influence of spacing on growth and yield attributes of bell pepper. The total yield was significantly higher at closer spacing of S_1 [45 × 45 cm] during 2012 only. However during 2011 and averaged over years the yield did not differ significantly between crop geometry of S1 [45 × 45 cm] and S_2 [60 × 45 cm]. The closer spacing with more number of plants per unit area compensated for the lesser yield attributes in comparison to wider spacing as a result the difference in yield was not significant between these two crop geometries. Similar results have been reported by Monirul Islam *et al*. (2011). Although the yield were statistically at par at S_1 [45 cm × 45 cm] and S_2 [60 × 45 cm] crop geometry but the net returns were INR 4487 more with S_2 [60 × 45 cm] crop geometry. The wider spacing requiring less seedlings per unit area and thereby lesser cost of planting which contributed to more returns in comparison to closer spacing. The B:C was also higher under the wider spacing than the closure one.

Effect of nitrogen level

Nitrogen is an essential macronutrient required by the plants for their growth, development and yield. It is the main constituent of all amino acids in proteins and lipids that acting as structural compounds of the chloroplast. Nitrogen fertilizer is an essential component of any system in which the aim is to maintain good yield (Law-Ogbomo and Egharevba, 2009; Bhuvaneswari *et al.,* 2014). In the present investigation also nitrogen levels brought about significant variation in growth, phenology, yield attributes and yield of bell pepper (Table 1 and 2). The number of branches per plant being statistically at par at 125% (N_2) and 150% (N_3) of recommended nitrogen level was higher than the present recommended N level (N_1). Increasing level of nitrogen from 100 to 150 per cent of recommended N significantly increased the number of days taken to 50% flowering and fruiting. This may partly be attributed to prolonged vegetative phase with higher nitrogen. The yield attributes *viz*. fruit length (4.63 cm), fruit width (4.62 cm), number of fruits per plant (9.05), fruit weight

Table 1 : Effect of spacing and fertility level on vegetative and reproductive characters of bell peppers

Treatment	Branches plant^{-1}			Days to 50% flowering			Days to 50% fruit set			Fruit length (cm)			Fruit width (cm)		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Spacing (cm)															
45×45	4.40	4.83	4.62	65	73	69	77	85	81	3.46	4.36	3.91	3.76	4.43	4.09
60×45	5.11	5.67	5.39	69	76	72	83	87	85	3.71	5.62	4.67	3.85	5.15	4.50
SEm(±)	**0.04**	**0.01**	**0.02**	**0.40**	**0.48**	**0.10**	**0.68**	**0.44**	**0.39**	**0.01**	**0.10**	**0.05**	**0.05**	**0.07**	**0.06**
LSD (0.05)	**0.16**	**0.05**	**0.08**	**1.72**	**2.08**	**0.41**	**2.91**	**Ns**	**1.67**	**0.04**	**0.44**	**0.20**	**ns**	**0.32**	**0.26**
Fertility level															
Recommended	4.11	4.50	4.30	62	69	66	76	81	78	3.20	4.54	3.87	3.41	4.45	3.93
125% Rec.N	4.94	5.33	5.14	66	75	70	80	87	83	3.65	5.08	4.37	3.86	4.82	4.34
150% Rec.N	5.22	5.92	5.57	72	80	76	84	91	87	3.91	5.34	4.63	4.15	5.10	4.62
SEm(±)	**0.19**	**0.02**	**0.19**	**0.64**	**0.61**	**0.52**	**0.82**	**0.36**	**0.54**	**0.05**	**0.05**	**0.05**	**0.07**	**0.09**	**0.05**
LSD (0.05)	**0.44**	**0.47**	**0.43**	**1.47**	**1.40**	**1.21**	**1.90**	**0.83**	**1.24**	**0.13**	**0.13**	**0.11**	**0.16**	**0.20**	**0.13**

Table 2: Effect of spacing and fertility level on reproductive parameters and economics of production

Treatment	Fruits plant^{-1}			Fruit weight (g)			Fruit weight plant^{-1} (g)			Yield (kg ha^{-1})			Net return (10^3 x INR ha^{-1})			B:C
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	
Spacing (cm)																
45×45	5.18	8.33	6.76	20.6	27.6	24.1	190.7	207.2	199.0	7038	10470	8754	52.4	121.0	86.7	1.88:1
60×45	7.18	9.85	8.51	23.7	33.1	28.1	204.2	221.4	212.8	6818	9939	8379	60.0	122.4	91.2	1.96:1
SEm(±)	**0.32**	**0.27**	**0.11**	**0.33**	**0.9**	**0.7**	**1.8**	**2.1**	**0.9**	**87.5**	**105**	**87.1**	**-**	**-**	**-**	**0.006**
LSD (0.05)	**1.38**	**1.15**	**0.49**	**1.4**	**3.9**	**3.0**	**7.7**	**8.9**	**3.6**	**NS**	**451**	**NS**	**-**	**-**	**-**	**0.035**
Fertility level																
Recommended	4.33	7.44	5.89	20.2	27.6	23.7	183.1	202.5	192.8	6394	9182	7788	45.7	101.5	73.6	1.83:1
125% Rec.N	6.66	9.27	7.97	22.0	30.1	26.1	199.8	215.2	207.5	6928	10159	8544	56.2	120.8	88.5	1.92:1
150% Rec.N	7.55	10.55	9.05	24.1	33.4	28.7	209.4	225.2	217.3	7463	11274	9368	66.6	142.9	104.7	2.01:1
SEm(±)	**0.08**	**0.35**	**0.16**	**0.7**	**0.5**	**0.5**	**0.7**	**1.3**	**0.9**	**68.5**	**151.0**	**79.8**	**-**	**-**	**-**	
LSD (0.05)	**0.19**	**0.80**	**0.38**	**1.7**	**1.1**	**1.1**	**1.6**	**3.1**	**2.1**	**158.0**	**348.0**	**183.9**	**-**	**-**	**-**	

(28.71g), fruit weight plant^{-1} (215.53 g) were highest at 150% of recommended N application (N_3) followed by 125% N application (N_2). With better yield attributes at higher nitrogen levels the yield also increased. Application of 150 kg (N_3) and 125 kg N ha^{-1} (N_2) increased the capsicum yield by 20.28 and 9.70 per cent, respectively, over recommended N application of 100 kg N ha^{-1} (N_1). Bhuvaneswari *et al.* (2014) also have reported response of bell peppers to nitrogen upto the 150 per cent of the recommended nitrogen in increasing its growth, yield attributes and fruit yield. Aminifard *et al.* (2012) reported similar findings. The net returns increased by rupee 31,154 and rupee 14,889 with application of 150 (N_3) and 125% N (N_2), respectively, over present recommended N application (N_1). Benefit cost ratio increased with increase in nitrogen rate from 100 to 150 per cent of the recommended showing that fertilizer application is remunerative upto 1.5 time of the existing dose.

From the present investigation it may be concluded that for higher sustainable capsicum yield and remunerative returns the crop can be grown with spacing at 60 x 45 cm and fertilized with 50 per cent more N (150 kg N ha^{-1}) than recommended one under dry temperate conditions.

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