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EFFECT OF DIFFERENT SPACING AND FERTIGATION LEVELS ON YIELD AND QUALITY OF BELL PEPPER (*CAPSICUM ANNUUM* L.) HYBRID BOMBY GROWN UNDER PROTECTED CONDITIONS

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ABSTRACT

A study was conducted to evaluate the effect of different spacing and fertigation levels on yield and quality of bell pepper hybrid 'Bomby' grown under protected conditions at Experimental Research Farm Chhapang of Dr. Khem Singh Gill, Akal College of Agriculture, Eternal University, Baru Sahib, Sirmaur (H.P.). The research trial consisted of nine treatment combinations including three different spacings (60 × 30 cm, 60 × 45 cm and 60 × 60 cm) and three fertigation levels (100, 150 and 200 kg NPK/ha). The experiment was laid out in randomized block design with three replications. The results revealed that among different spacings, S_3 (60 × 60 cm) was superior in most of observed parameters except fruit yield per m^2 (kg) and fruit yield per hectare (t) where S_2 (60 × 45 cm) was best. Whereas minimum days of flower initiation, minimum days to first picking, harvest duration and ascorbic acid content (mg/100g) S_1 (60 × 30 cm) resulted best. However, fertigation level F_3 (200 kg NPK/ha) stood out to be best for most of the parameters except fruit length (cm), fruit breadth (cm) and pericarp thickness (mm) where F_2 (150 kg NPK/ha) was best, whereas for earliness and harvest duration F_1 (100 kg NPK/ha) resulted best. The results revealed that interaction was found to be significant only for the characters i.e., fruit length (cm), fruit weight (g), fruit yield per plant (kg), fruit yield per m^2 (kg) and fruit yield per hectare (t). Therefore, spacing of 60 × 60 cm combined with the application of 200 kg NPK/ha for bell pepper production under protected condition is optimal and can be used by growers to increase yield.

Keywords: Bell pepper, fertigation, interaction, protected conditions, quality, spacing, yield

Introduction

Bell pepper (*Capsicum annuum* L.), often called as capsicum or Shimla mirch, is one of the highly remunerative vegetable crops grown in polyhouses. It has the chromosomal number (2n=2x=24) and belongs to the Solanaceae family. Its primary centre of origin is Tropical South America and Guatemala being its secondary centre of origin (Jakhar *et al.*, 2017; Heiser and Smith, 1953). The Britishers introduced it to India in the 19th century in the Shimla hills (Ngupok *et al.*, 2018). It can be eaten raw as a salad or cooked as a dish and also as a condiment (Jakhar *et al.*, 2017). Because of their mild pungency and flavour, bell pepper fruits (green, red and yellow coloured) are commonly used in stuffings, baking, pizza, and burger preparations. It is a high economic return vegetable crop that is grown in many parts of the world, notably in Europe, Central and South America and in Asia's tropical and subtropical regions (Shivakumar *et al.*, 2012). China is the world's leading producer of capsicum. With an average yearly production of 515 thousand million tonnes from an area of 34 thousand hectares and an average productivity of 15.147 tons/hectare, India accounts for one-fourth of global bell pepper production (NHB 2019-2020). It is commercially grown in Himachal Pradesh, Jammu and Kashmir, Uttarakhand, Arunachal Pradesh and Darjeeling district of West Bengal during summer season and as an autumn crop in Maharashtra, Karnataka, Tamil Nadu, Uttar Pradesh and Bihar (Ngupok *et al*., 2018). In Himachal Pradesh bell pepper growing area is about 2.5 thousand hectares and total production of 58.29 thousand million tonnes (NHB, 2019-20). It is primarily grown in Shimla, Solan, Sirmaur and Mandi districts of Himachal Pradesh. Bell pepper is grown year-round in greenhouses in various parts of India, including Himachal Pradesh, Maharashtra and Karnataka. Farming capsicum in protected environments such as green houses or polyhouses is essential during the off-season to ensure high-quality yield and production. Capsicum cultivation in polyhouse, not only increases the productivity but also, enhances the quality of crop (Kumar *et al*., 2018). Bell pepper has attained a status of high-value crop in India in recent years and it takes pride place among the vegetables in Indian cuisine due to its delicacy and pleasant flavour. It has high nutritional profile, with rich source of vitamin A (180 IU), thiamin, niacin, Vitamin C (283 mg) and minerals like calcium (13.4 mg), magnesium (14.9 mg), phosphorus (28.3 mg) and potassium (263.7 mg) per 100 g fresh fruit weight (Thakur *et al*., 2018). It also contains a high amount of β-carotene and capsanthin, which makes up around 36% of the total carotenoid content with good amount of rutin (a bioflavonoid) as well. Because of the high concentrations of antioxidant, capsaicin and capsanthin as key active ingredients, it is one of the most lucrative medicinal plants in the pharmaceutical industry (Aminifard *et al*., 2012). Capsicum's bioactive components work synergistically to improve blood flow, act as a cancer preventative, painkiller, protect the stomach mucosa and provide essential nutrients for a healthy living (Clement *et al*., 2012).

Plant spacing is an important feature of successful crop production in both open and protected environments. Planting distance is vital for controlling plant growth, improving fruit qualities and increasing crop production with improved land use efficiency (Athira and Rani, 2020). In a polyhouse, the wide row spacing of plants boosts per plant yield but reduces crop production per unit area (Islam *et al*., 2011). Higher plant density resulted in lower fruit weight from early yield, which is linked to fruit size and is crucial because it decides prices of bell pepper (Sangma *et al*., 2018). It also has a significant impact on the fruit's quality characteristics (Mantur *et al*., 2005). Application of fertilizers in combination with the irrigation system is known as fertigation, which is another key component of protected cultivation that effects production and quality of yield (Saurabh and Singh, 2019). It is a well-known fact that macronutrients like nitrogen, phosphorus and potassium have a significant impact on crop productivity and quality (Ngupok *et al*., 2018). Fertigation through drip irrigation allows nutrients to be applied precisely and consistently to the rhizosphere, increasing fertilizer efficiency (Locascio, 2005). Nowadays, use of water-soluble fertilizers is on the rise, but there is still a lack of basic information about fertigation scheduling in vegetable crops. There have been few attempts to determine the best fertilizer schedules for capsicum, especially under protected farming. As a result, optimal spacing combined with efficient and optimum fertilizer application under protected conditions provides improved bell pepper growth, production and quality, as well as reduced input losses and greater economic benefits (Athira and Rani, 2020).

Materials and Methods

The experiment was carried out under protected conditions during *Kharif*, 2021 at Experimental Research Farm Chhapang of Dr. Khem Singh Gill, Akal College of Agriculture, Eternal University, Baru Sahib, Sirmaur-173101 (H.P.). Bomby hybrid of Syngenta Private Limited was the planting material used in the experimental trial. With three replications, the trial included nine possible treatment combinations laid out in randomized block design (RBD). Plot size was 2×1m. The treatments comprised of three different spacings *viz*., S_1 (60 × 30 cm), S_2 (60 × 45 cm) and S_3 (60 × 60 cm) and three fertigation levels *viz*., F_1 (100 kg NPK/ha), F_2 (150 kg NPK/ha) and F_3 (200 kg NPK/ha). Polyfeed (19:19:19) which is a water-soluble form of fertilizer, was utilized for fertilizer application with irrigation.

Results and Discussion

Quantitative Parameters

For traits contributing towards yield, desired significant value among all the three spacings for flower initiation, days to first picking and harvest duration was recorded in S_1 (60 × 30 cm). F_1 (100 kg NPK/ha) among all fertigation levels was observed with the highest significant value for the same. Their interaction effect on these characters, on the other hand, was not significant. This earliness and longer harvest duration compared to wider spacing could be attributable to the plant’s better vegetative growth in wider spacing, since high nutrition, particularly N fertilization, would have extended the vegetative period.

Table 1 : Effect of different spacing and fertigation levels on quantitative parameters of bell pepper (*Capsicum annuum* L.)

Treatment	Flower Initiation (days)	Days to first picking	Fruit Length (cm)	Fruit Breadth (cm)	Fruit Weight (g)	Harvest Duration (days)	Yield per plant (kg)	Yield per m^2 (kg)	Yield per hectare (t)
Spacing (S)									
S_1	54.56	106.89	6.75	7.09	156.95	60.11	1.15	9.21	78.28
S_2	56.67	108.44	7.28	7.47	162.79	58.67	1.65	9.92	84.31
S_3	57.11	109.78	7.46	7.78	184.90	57.33	2.20	8.80	74.82
SEm (S)	0.317	0.582	0.064	0.074	1.225	0.463	0.033	0.064	0.75
$CD_{0.05}$ (S)	0.958	1.761	0.194	0.225	3.703	1.399	0.101	0.193	2.267
Fertigation Levels (F)									
F_1	55.33	107.11	7.00	7.27	159.94	59.78	1.50	8.44	71.70
F_2	56.44	108.44	7.34	7.61	169.09	58.78	1.64	9.20	78.18
F_3	56.56	109.56	7.15	7.46	175.60	57.56	1.86	10.30	87.53
SEm (F)	0.317	0.582	0.064	0.074	1.225	0.463	0.033	0.064	0.75
$CD_{0.05}$ (F)	0.958	1.761	0.194	0.225	3.703	1.399	0.101	0.193	2.267
Interaction effect (S×F)									
S_1F_1	53.00	106.00	6.40	6.95	151.57	61.00	1.04	8.31	70.67
S_1F_2	55.00	107.00	7.16	7.21	159.50	60.00	1.15	9.18	78.02
S_1F_3	55.67	107.67	6.68	7.12	159.77	59.33	1.27	10.14	86.15
S_2F_1	56.33	107.00	7.25	7.35	159.88	59.67	1.57	9.41	79.99
S_2F_2	57.00	107.67	7.27	7.49	165.29	59.33	1.65	9.94	84.46
S_2F_3	56.67	110.67	7.32	7.56	163.21	57.00	1.73	10.41	88.47
S_3F_1	56.67	108.33	7.35	7.52	168.39	58.67	1.90	7.58	64.43
S_3F_2	57.33	110.67	7.59	8.12	182.49	57.00	2.12	8.48	72.06
S_3F_3	57.33	110.33	7.45	7.72	203.81	56.33	2.59	10.35	87.96
SEm(S×F)	0.549	1.008	0.111	0.129	2.121	0.801	0.058	0.111	1.298
$CD_{0.05}$(S×F)	NS	NS	0.335	NS	6.413	NS	0.175	0.334	3.926

However, plants at low plant spacing on the other hand, experienced less vegetative growth, resulting in an earlier entry into the reproductive stage, a faster maturity and a longer fruit-producing period. Kumar and Rana 2018, Sangma *et al.*, 2018, Kaur *et al.*, 2017, Ganjare *et al.*, 2013 and Thakur *et al.*, 2018 also reported the similar results as in the present study. For other yield influencing characters like fruit length, fruit breadth and fruit weight, spacing responded significantly where S_3 (60 × 60 cm) was superior. As for fertigation level, F_3 (200kg NPK/ha) was found significantly superior for fruit weight while, F_2 (150kg NPK/ha) was superior for fruit length and fruit breadth but was statistically very close to F_3. However, the interaction between spacing and fertigation was significant for fruit length and fruit weight where treatment combination S_3F_2 was superior for fruit length and treatment combination S_3F_3 for fruit weight. Further their interaction impact was non-significant for fruit breadth. Another reason could be that at wider spacing, there is less competition for available water and mineral nutrients from the soil, as well as light, resulting in the accumulation of sufficient photosynthates, allowing the fruits to grow in size (length and breadth), resulting in increased fruit weight. Athira and Rani, 2020, Kumar and Rana 2018, Kumar *et al.*, 2018, Sangma *et al.*, 2018, Islam *et al.*, 2011 and Shivkumar *et al.*, 2012 all found similar results. Different spacing and fertigation levels as an individual factor responded strongly to yield traits like fruit yield per plant, fruit yield per m^2 and fruit yield per hectare. S_3 (60 × 60 cm) and application of NPK @ 200 kg/ha as individual factor produced highest significant value for fruit yield per plant. This could be because the plants were able to develop properly with reduced inter- and intra-plant competition for utilising the limited resources, resulting in a better yield per plant. Also, increased yield per plant must have resulted from the constant and optimal availability of nutrients at a higher rate during the whole plant growth cycle. Furthermore, S_2 (60 × 45 cm) and NPK @ 200 kg/ha were found to be superior for fruit yield per m^2 and fruit yield per hectare. The reason for this could be due to a higher plant population in spacing S_2 than S_3, as well as more fruits per plant and higher fruit weight in S_2 than in S_1, despite the fact that the number of plants in S_1 was higher. Moreover, their interaction had a substantial impact on yield characteristics, where treatment combination of S_3F_3 (60 × 60 cm + 200 kg NPK/ha) brought maximum fruit yield per plant and treatment combination of S_2F_3 (60 × 45 cm + 200 kg NPK/ha) recorded for maximum fruit yield per m^2 and fruit yield per hectare. The findings of Athira and Rani 2020, Nandeshwar and Bharad 2019, Kumar and Rana 2018, Kumar *et al*. 2018, Sangma *et al*. 2018, Biwalker *et al*. 2015, Ganjare *et al*. 2013 and Aminifard *et al*. 2012 all support the present results.

Qualitative Parameters

Table 2 : Effect of different spacing and fertigation levels on qualitative parameters of bell pepper (*Capsicum annuum* L.)

Treatment	Pericarp thickness (mm)	TSS (°Brix)	Ascorbic acid content (mg/100g)	Carotenoid content (mg/100g)
Spacing (S)				
S_1	4.87	4.79	161.56	2.78
S_2	5.14	5.04	154.44	3.50
S_3	5.58	5.30	137.56	4.23
SEm (S)	0.084	0.050	2.092	0.124
$CD_{0.05}$ (S)	0.253	0.150	6.324	0.374
Fertigation Levels (F)				
F_1	5.02	4.98	146.00	3.14
F_2	5.36	4.99	152.67	3.58
F_3	5.21	5.16	154.89	3.78
SEm (F)	0.084	0.050	2.092	0.124
$CD_{0.05}$ (F)	0.253	0.150	6.324	0.374
Interaction effect (S×F)				
S_1F_1	4.79	4.73	158.00	2.32
S_1F_2	4.92	4.75	164.00	2.84
S_1F_3	4.90	4.89	162.67	3.18
S_2F_1	4.99	5.01	152.00	3.31
S_2F_2	5.23	5.01	158.00	3.53
S_2F_3	5.20	5.11	153.33	3.66
S_3F_1	5.28	5.19	128.00	3.80
S_3F_2	5.93	5.22	136.00	4.37
S_3F_3	5.54	5.49	148.67	4.51
SEm(S×F)	0.145	0.086	3.623	0.214
$CD_{0.05}$(S×F)	NS	NS	NS	NS

Different spacing and fertigation levels responded strongly to ascorbic acid content, with the highest significant value in S_1 (60 × 30 cm) and F_3 (200 kg NPK/ha), where F_2 and F_3 were statistically identical. This rise in ascorbic acid concentration could be attributed to closer spacing, which increased plant competitiveness for resources and water, resulting in increased essential metabolic activity and organic acid generation. Another reason could be related to the availability of soluble nutrients in the soil during the active growing period, which may have resulted in carbohydrate assimilation and, as a result, ascorbic acid synthesis. Nandeshwar and Bharad 2019, Ngupok *et al*., 2018, Biwalkar *et al*., 2015, Aminifard *et al*., 2012, Bassiony *et al*., 2010, Ananthi *et al*., 2004 and Ramakrishna and Palled 2004 found similar results as in the present study. The interaction impact of the two components was non-significant once more. Similar significant effects of spacing and fertigation were observed for the other two qualitative traits, total soluble solids and carotenoid content, with the highest significant value in the S_3 (60 × 60 cm) and F_3 (200 kg NPK/ha) treatments. In terms of carotenoid concentration, however, treatment F_3 was statistically equivalent to treatment F_2. This increase in total soluble solids and carotenoid content with increased spacing and fertigation levels could be due to the positive effect of wider spacing on plant vegetative growth and sugar assimilation, as well as increased availability of major and minor nutrients in the treatment, particularly N and K, which are important in improving fruit quality. Bijeta *et al*. 2019 and Singh *et al*., 2010 observed similar trends of increase in total soluble solids with increasing spacing and fertigation levels, while Nandeshwar and Bharad 2019, Bijeta *et al*., 2019 and Ngupok *et al*., 2018 reported similar trends in carotenoids.

Conclusion

The effects of spacing (60 × 60 cm) combined with 200 kg NPK/ha fertigation on bell pepper were found significantly superior for most of the yield and contributing traits. Furthermore, applying nutrients more often during the crop growth period allowed for maximal nutrient and water absorption, resulting in increased photosynthate translocation to reproductive parts and crop growth and production. Similarly, the economic analysis of the study found clear evidence of improved bell pepper yield, which resulted in significant economic benefits. As a result, for bell pepper production in polyhouse, a spacing of 60 × 60 cm combined with the application of 200 kg NPK/ha is excellent and can be utilized by bell pepper growers to improve yield under protected conditions with efficient use of land.

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