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Effect of plant spacing on growth, flowering, fruiting and yield of Capsicum (*Capsicum annuum* L) hybrid buffalo under natural ventilated polyhouse

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Abstract
An experiment was carried out to study the Effect of plant spacing on growth, flowering, fruiting and yield of Capsicum (*Capsicum annuum* L) hybrid buffalo under natural ventilated polyhouse during September, 2016 to February, 2017 at Hi-Tech Horticulture, Dr.R.P.C.A.U Pusa, Samastipur, Bihar. There were three levels of spacing 45 cm x 30 cm (4.4 plants/m^2), 45 cm x 45 cm (2.94 plants/m^2) and 45 cm x 60 cm (2.22 plants/m^2) and three levels of numbers of shoots per plant *viz*. two shoots, three shoots and four shoots. The experiment was laid out in factorial randomized block design with three replications.

Among the different spacing level, the spacing S_1 (45 cm x 30 cm) recorded maximum plant height (137.46 cm), yield (82.13t/ha.) and spacing S_1 (45 cm x 30 cm) showed the early flower initiation as well as 50 per cent flowering (52.24 days). Maximum number of leaves (122.29), leaf area (97.24 dm^2), number of branches (9.39), number of flower per plant (10.74), number of days for fruit set (66.20), least number of days to first harvest (89.06 days), fruit weight (185.31g), number of fruit per plant (18.48), yield per plant (3.38 kg.) was recorded under S_3(45 cm x 60 cm) and higher B:C ratio (5.60) was recorded under S_2 rest of treatments.

Keywords: Capsicum, spacing, training, natural ventilated polyhouse

Introduction
The genus capsicum belongs to the family Solanaceae which is grown in several part of the world and is believed to be native of Tropical South America (Shoemaker and Teskey, 1995) [12]. The domesticated pepper could be broadly classified into sweet and hot types based on their levels of pungency. Capsicum (*Capsicum annuum* L. var. grossum Sendt; 2n =24) also known as Bell pepper or Sweet pepper or Green pepper or Shimla mirch. They differ from common hot peppers in size and shape of the fruits, capsaicin content and usage. Capsicum is one of the popular solanaceous vegetable crops grown throughout India in open as well as protected environments. It is extensively cultivated in hills of Himachal Pradesh, Uttar Pradesh, Jammu and Kashmir, Andhra Pradesh and Nilgiri hills during summer months. As an autumn crop, it extends up to winter months in Karnataka, Maharashtra, Tamil Nadu, Bihar, West Bengal, Uttar Pradesh and Madhya Pradesh. Bell pepper/capsicum is one of the highly remunerative vegetables cultivated in most part of the world especially in temperate regions of central and South America and European countries, tropical and subtropical regions of Asian continent. In the world, area and production of bell pepper is merged with that of hot pepper (chilli pepper). Hence, the exact statistics related to bell pepper/chilli as whole is given. China is the major producer of capsicum and contributes 36 per cent of the worlds cultivated area with a production of 15.03 million tones. India contributes average annual production of 1.08 million tonnes from an area of 1.06 million hectare with a productivity of 1.12 tonnes per ha (Anon., 2014) [2]. Capsicum attained a status of high value low volume crop in India in recent years and occupies a place of pride among vegetables in Indian cuisine, because of its delicacy and pleasant flavour coupled with rich content of ascorbic acid along with other vitamins and minerals (Kurubetta and Patil, 2009) [6]. Nutritionally, it is rich in vitamin-A (8493 IU), 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. Capsicum is also good source of β-carotene and capsanthin which accounts for about 36 per cent of the total carotenoid content. Violaxanthin for about 10 per cent, cryptoxanthin and capsorubin for 6 per cent each and cryptocapsin for about 4 per cent are other carotenoids present in capsicum. Bell pepper has attained a status of high value crop in India in recent years and occupies a pride of

Place among vegetables in Indian cuisine because of its delicacy and pleasant flavour coupled with rich content of ascorbic acid and other vitamins and minerals. Nutritionally, bell peppers are rich in vitamins particularly vitamin A (180 IU) and vitamin C. 100 gm of edible portion of capsicum provides 24 Kcal of energy, 1.3 g of protein, 4.3 g of carbohydrate and 0.3 g of fat (Anon., 2001) [1]. It also finds place in preparations like pizza stuffing's and burger with growing popularity of fast food. The high market price is attributed to the heavy demand from the urban consumers. There is a good demand for export too. The export market needs fruits with longer shelf life, medium size tetra lobed fruit with attractive colour, mild pungency with good test. However the supply is inadequate due to the low productivity of the crop (Muthukrishnan *et al*., 1986) [8].

The search for new avenues has led to development of Hi-Tech precision agricultural systems. Green house, the latest word in Indian agriculture is one such means, where the plant are grown under controlled or partially controlled environment resulting in higher yields than that is possible under open conditions (Navale *et al*., 2003) [10]. Considering the above facts, the present study on capsicum was taken up.

Material and Methods

The present investigation was carried out at Hi-Tech Horticulture, Dr.R.P.C.A.U PUSA, Samastipur, Bihar during September, 2016 to February, 2017 to study the performance of hybrid capsicum (*Capsicum annuum* L.) cv. Buffalo with different levels of spacing under naturally ventilated polyhouse. The seedlings of capsicum hybrid buffalo was planted in two rows on one meter wide bed having 50 cm path between two beds with three spacing levels S_1(45 x 30 cm), S_2(45 x 45 cm), S_3(45 x 60 cm) and three training levels P_1 (two shoots/plant), P_2 (three shoots/plant) and P_3 (four shoots/plant). Plants were trained with plastic thread tied to galvanized iron wire stretch over head along the bed. The experiment was laid out in a two factor factorial plot design with three replications. The total numbers of treatments were nine. Irrigation and fertilizer were done as per the recommendation. The misting was carried out by over head mister as per need to bring temperature and relative humidity up to optimum level in polyhouse**.** The polyhouse was heated at night to maintain a minimum temperature of 16 ºC. Maximum temperatures (day time) inside the polyhouse depended on the outside air temperatures and varied from 20 ºC to 34 ºC during the cultivation period. A drip irrigation system was used for irrigation and fertilization. During the experiment Vermicompost 3 kg/m^2, N: P: K 150:150:150 Kg/ha in the form of 19:19:19 water soluble fertilizer was applied alternate day with the help of fertigation unit. Micronutrient solutions were applied through foliar spray @ 2.0 ml per liter of water at monthly interval during crop period. Five plants were tagged at random in each treatment for recording the plant height at an interval of 30 days starting from the date of transplanting. The plant height was measured from the ground level to the growing tip of the main stem and number of leaves from each of five labelled plants was counted and recorded at 30 days interval at 30, 60, 90 and 120 days after transplanting (DAP). The average height was calculated and expressed in centimeters. Five mature photosynthetically active leaves were separated from selected plants of all the treatments. The leaf area was measured using portable leaf area meter (Licor-3000) and expressed in deci sq. m. According to treatments, branches were kept fixed in number per plant. Number of flowers that bloomed was recorded at regular intervals from commencement of flowering to final harvest and total number of flowers per plant was recorded. The number of days taken after planting for 50 per cent of the plants for first flowering was recorded as days to 50 per cent flowering. Number of days taken from the date of transplanting for the first fruit set and first harvest appearance were counted and recorded. The fresh weight of capsicum fruits harvested from the labeled plants from each treatment were weighed and recorded in grams. The number of set fruits from tagged plants were recorded from 60, 90, 120, 150 and 180 DAP. 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 and Total weight of matured fruits harvested from each picking in the tagged plants in each replication was recorded till final harvest and the total yield of fruits per hectares under different treatments computed in tones per hectare. Economics of capsicum production under polyhouse was worked out by considering the present price of inputs and produce

Table 1: Effect of plant spacing on plant height (cm) of capsicum hybrid buffalo at different stage of crop growth

Treatment	Plant height (cm) at 30 DAP	Plant height (cm) at 60 DAP	Plant height (cm) at 90 DAP	Plant height (cm) at 120 DAP
S_1 (45 cm x 30 cm)	44.56	84.73	117.89	137.46
S_2 (45cm x 45cm)	41.83	79.84	111.46	125.63
S_3(45cm x 60cm)	32.70	69.34	96.50	107.38
S.Em(±)	1.53	1.89	3.10	3.44
LSD(0.05)	4.59	5.67	9.30	10.32
CV%	11.57	7.28	8.56	8.37

Table 2: Effect of plant spacing on number of leaves of capsicum hybrid buffalo at different stage of crop growth

Treatment	No. of leaves at 30 DAP	No. of leaves at 60 DAP	No. of leaves at 90 DAP	No. of leaves at 120 DAP
S_1 (45 cm x 30 cm)	36.91	73.87	92.50	98.67
S_2 (45cm x 45cm)	43.29	77.44	102.77	109.49
S_3(45cm x 60cm)	48.36	82.74	107.42	122.29
S.Em(±)	1.38	2.31	2.85	3.43
LSD(0.05)	4.13	6.93	8.53	10.29
CV%	9.63	8.89	8.46	9.35

Table 3: Effect of plant spacing on number of flower per plant of capsicum hybrid buffalo at different stage of crop growth

Treatment	Number of flower per plant at 60 DAP	Number of flower per plant at 90 DAP	Number of flower per plant at 120 DAP	Number of flower per plant at 150 DAP	Number of flower per plant at 180 DAP
S_1 (45 cm x 30 cm)	7.62	8.07	7.03	5.30	2.34
S_2 (45cm x 45cm)	9.18	10.16	8.68	7.05	2.92
S_3(45cm x 60cm)	10.19	10.74	9.27	7.80	3.56
S.Em(±)	0.33	0.32	0.26	0.22	0.11
LSD(0.05)	0.98	0.97	0.76	0.66	0.33
CV%	10.87	9.96	9.18	9.84	11.43

Table 4: Effect of plant spacing on Leaf area(dm^2), Number of branches per plant at 120 DAP, Days to 50% flowering, Number of days for fruit set, Days to first harvest of capsicum hybrid buffalo at different stage of crop growth

Treatment	Leaf area(dm^2)	Number of branches per plant at 120 DAP	Days to 50% flowering	Number of days for fruit set	Days to first harvest
S_1 (45 cm x 30 cm)	83.15	6.07	52.24	60.90	98.08
S_2 (45cm x 45cm)	95.91	7.80	54.49	64.56	92.96
S_3(45cm x 60cm)	97.24	9.39	56.83	66.20	89.06
S.Em(±)	2.68	0.33	1.66	1.22	1.66
LSD(0.05)	8.03	1.00	4.98	3.66	4.98
CV%	8.73	12.44	9.14	5.73	5.31

Table 5: Effect of plant spacing on Fruit weight (g), Number of Fruit per plant, Fruit yield / plant(Kg), Yield (t / ha), and B : C ratio of capsicum hybrid buffalo at different stage of crop growth

Treatment	Fruit weight (g)	Number of Fruit per plant	Fruit yield / plant(Kg)	Yield (t / ha)	B : C ratio
S_1 (45 cm x 30 cm)	139.66	13.43	1.89	82.13	4.17
S_2 (45cm x 45cm)	167.03	16.60	2.74	80.75	5.60
S_3(45cm x 60cm)	185.31	18.48	3.38	75.10	5.38
S.Em(±)	6.52	0.84	0.08	2.65	0.15
LSD(0.05)	19.55	2.52	0.24	7.96	0.46
CV%	11.93	15.58	8.85	10.03	10.09

Result and Discussion

The highest plant height (44.56 cm), (84.73 cm), (117.89 cm), (137.46 cm) was recorded under S_1 (45 cm x 30 cm) spacing which was statistically at par with S_2 (45 cm x 45 cm) and significantly superior over S_3 at 30, 60, 90, 120 DAP respectively. This might be due to the great competition for space and light thereby forcing the plants to grow taller. The short and stout plants were produced at wider spacing S_3 because of availability of more growth space where in plants were able to exploit more nutrients from the soil and light sources. Similar increase in growth rate at closer spacings were noticed and reported by Pandey *et al*. (1997) [11], Gupta and Shukla (1977) [3] in tomato, Srinivas (1982) [13], Stoffella and Bryan (1988) [14, 15] in capsicum.The highest number of leaves (48.36), (82.74), (107.42) and (122.29) was recorded under S_3 (45 cm x 60 cm) spacing at 30, 60, 90, and 120 DAP respectively, which was significantly superior over S_1 (45 cm x 30 cm) and S_2 (45 cm x 45 cm). This may be attributed to stout plants produced by exploiting the available space, nutrients and light resources favoring fast vegetative growth. Similar results of more number of leaves in wider spacing were observed by Pandey *et al.* (1997) [11] in tomato, Stoffella and Bryan (1988) [14, 15] in bell pepper and Harminder Singh *et al*. (1997) [4] in Brinjal. The leaf area per plant at different spacing levels at 90 DAP, the highest number of leaf area (97.24 dm^2) was recorded under S_3 (45 cm × 60 cm) spacing which was statistically at par with S_2 (45 cm×45 cm) and significantly superior over S_1(45 cm × 30 cm). This may due to the availability of more space to spread, more moisture and nutrients and solar radiation compared to other spacing S_1 and S_2. The same results were obtained by Pandey *et al*. (1997) [11] in tomato. The number of branches per plant at different spacing levels at 120 DAP, the highest number of branches per plant (9.39) was recorded under S_3 (45 cm x 60 cm) spacing which was significantly superior over S_2 (45 cm x 45cm) and S_1 (45 cm x 30 cm). This may due to wider space because of vigorous and healthy plants as compared to other spacing. The highest number of flower per plant (10.19), (10.74), (9.27), (7.80), (3.56) was recorded under S_3 (45 cm x 60 cm) spacing which was statistically at par with S_2 (45 cm x 45 cm) and significantly superior over S_1 at 60, 90, 120, 150, and 180 DAP respectively. which could be due to the faster growth and higher number of secondary branches. Number of days to 50 per cent flowering was also significantly influenced by plant spacing, the spacing S_1 produced early (52.24 days) 50 per cent flowering followed by spacing S_2 (54.49 days). The late (56.83 days) 50 per cent flowering was observed in spacing S_3 (56.83), which was at par with spacing S_2 (54.49 days). Which might be due to availability of good sunshine and nutrients in the soil resulting in the accumulation of more photosynthesis and induction of early flowering compared to other spacing. Among different spacing levels of number of days for fruit set, the highest number of days for fruit set (66.20) was observed under S_3 (45 cm × 60 cm) spacing which was statistically at par with S_2 (45 cm × 45 cm) and significantly superior over S_1 (45 cm × 30 cm). which could be due to the more number of flowers because of vigorous and healthy plants. The early (89.06 days) harvesting was observed under S_3 (45 cm × 60 cm) followed by medium spacing S_2 (92.96 days) and late (98.08 days) harvesting was noticed in spacing S_1.It could be due to the early fruit set, coupled with exposure of fruits to sunlight and better aeration in these treatments. Comparatively late harvesting was observed under closer spacing S_1 and training level P_3 due to the dense canopy of plants. Under the different spacing levels, the highest number of fruit weight (185.31 g) was recorded under S_3 (45 cm × 60 cm) spacing which was statistically at par with S_2 (45 cm × 45cm) and significantly

superior over S_1 (45 cm × 30 cm). This could be due to the increased uptake of more nutrients and buildup of sufficient photosynthates enabling the increase in size of fruits (length and breadth), ultimately resulted in the increased fruit weight. Similar findings were reported by Joshi *et al*. (1980) [5] in tomato, Harminder Singh *et al*. (1997) [4] in brinjal and Nagendra Prasad (2001) [9] in capsicum. The maximum number of fruits per plant (18.48) was recorded under S_3 (45 cm × 60 cm) spacing which was statistically at par with S_2 (45 cm × 45 cm) and significantly superior over S_1 (45 cm × 30 cm). This may due to the more number of flowers because of vigorous and healthy plants. Among different spacing levels of yield per plant, the highest number of yield per plant (3.38 kg) was observed in S_3 (45 cm × 60 cm) spacing which was significantly superior over S_2 (45 cm × 45 cm). This might be due to the higher number of flowers, fruits and maximum extent of fruit set. Under different spacing levels, the highest yield (82.13 t/ha) was recorded under S_1 (45 cm × 30 cm) spacing which was statistically at par with S_2 (45 cm × 45 cm) and significantly superior over S_3 (45 cm × 60 cm). This might due to higher plant density per unit area. The increase in plant population was leads to increase in total and marketable yield of capsicum. Similar results were observed by Srinivas (1982) [13] and Manchanda and Bhopal Singh (1988) [7], Pandey *et al*. (1997) [11] in tomato, Joshi *et al*. (1980) [5] and Harminder Singh (1997) [4] in brinjal. Under different spacing levels, the highest B: C ratio (5.60) was observed in S_2 (45 cm × 45 cm) spacing which was statistically at par with S_3 (45 cm × 60 cm) and significantly superior over S_1 (45 cm × 30 cm). It may due to better quality and higher yield obtained than other treatments.

Conclusion

After the experiment effectuated in 2017 regarding the Effect of plant spacing on growth, flowering, fruiting and yield of Capsicum (*Capsicum annuum* L) hybrid buffalo under natural ventilated polyhouse. The following conclusions can be inferred

In the case of different types of characters like plant height, yield (t/ha.) was recorded under spacing S_1 (45 cm x 30 cm) and spacing S_1 (45 cm x 30 cm) showed the early flower initiation as well as 50 per cent flowering. Maximum number of leaf, leaf area, number of branches, number of flower per plant, number of days for fruit set, least number of days to first harvest, fruit weight, number of fruit per plant, yield per plant was recorded under S_3(45 cm x 60 cm) and higher B:C ratio was recorded under S_2 rest of treatments.

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