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Response of different plant densities and training levels on yield and quality of capsicum (*Capsicum annum* L.) variety Indra under polyhouse condition

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Abstract
The present investigation entitled "Response of different plant densities and training level on yield and quality of capsicum (*Capsicum annum* L.) variety Indra under polyhouse". The experiment was laid out in two factorial RBD using three replications with three levels of spacing and training under protected condition at Department of Horticulture, VNMKV, Parbhani (MH) during 2016-2017. The closer spacing S_1 (60 x 30 cm) recorded highest marketable yield per hectare (55.09 t/ha), total yield (55.43 t/ha), lowest unmarketable yield (0.04 kg) highest yield per harvesting (9.68) whereas, wider spacing S_3 (60 x 60 cm) recorded highest marketable yield per plant (1.82 kg), yield per plant (1.96 kg), individual fruit weight (115.87 g), fruit breadth (8.00 cm), fruit length (10.47 cm). Among the different training levels T_1 (two shoots) training recorded highest individual fruit weight (115.92 g), fruit breadth (8.40 cm) and fruit length (10.81 cm), lowest unmarketable yield per plant (0.04 kg). Highest marketable yield per plant (1.20 kg) was noticed with T_2 (three shoots) training. Highest marketable yield per hectare (61.94 t/ha), yield per plant (1.84 kg), maximum yield per harvesting (10.64), total yield (63.97 t/ha) was recorded in T_3 (four shoots) training. Among all interactions S_1T_1 (60 x 30 cm and two shoots) recorded minimum unmarketable fruit yield per plant (0.02 kg). Treatment combination S_1T_3 (60 x 30 cm with four shoot) recorded highest yield per harvesting (13.41 kg), marketable yield per hectare (77.77 t/ha) and total yield per hectare (78.88 t/ha). In contrast, S_3T_1 (60 x 60 cm with two shoots training) recorded highest individual fruit weight (137.07 g), fruit breadth (8.80 cm), fruit length (12.13 cm). S_3T_3 (60 x 60 cm with four shoot) recorded highest marketable yield per plant (2.54 kg) and yield per plant (2.78 kg).

Keywords: Capsicum, yield, quality, protected cultivation, spacing, training

Introduction
Capsicum (*Capsicum annum* L.) belongs to the family solanaceae under the genus capsicum. Bell pepper was brought to India by British in 19th century in Shimla, Himachal Pradesh and Nilgiri hills of Tamil Nadu. Sweet pepper is used either green or red, and may be eaten as cooked or salad. It also used for pickling in brine, baking and stuffing. The leaves are also consumed as salad, soup or eaten with rice. It was also discovered to be a good source of medicinal preparation for black vomit, tonic for gout and paralysis (Knott and Deanon, 1967) [5]. Bell pepper is a cool season tropical crop and lacks adaptability to varied environmental conditions. But still growers are not in a position to produce good quality capsicum with high productivity due to various biotic, abiotic and crop factors. To overcome such constraints in production of off season capsicum there is need to cultivate capsicum under protected conditions such as green houses or polyhouses or shadenet houses. Planting distance plays an important role in checking the growth of plant, improving fruit characteristics and increasing the yield. Optimum plant spacing ensures proper growth and development resulting maximum yield of crop and economic use of land. 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, high yield of large sized fruits. There is no such information available on polyhouse cultivation of capsicum and its response to varying plant population and training levels. There is a need to assess suitable plant spacing and optimum training levels for cultivation of capsicum under polyhouse condition.

Materials and methods
To assess the response of different plant densities and training level on yield and quality of capsicum (*Capsicum annum* L.) variety Indra under polyhouse, an experiment was laid out at Department of Horticulture, Vasantrao Naik Marathwada Agricultural University, Parbhani

during 2016-2017. The size of polyhouse was 28 m x 20 m (560 m^2). The experiment was comprised of three levels of spacing i.e., 60 x 30 cm (S_1), 60 x 45 cm (S_2), 60 x 60 cm (S_3) and three levels of training Viz, two shoots (T_1), three shoots (T_2), four shoots (T_3). 40 days old seedlings at 4-5 leaf stage were transplanted at 60 x 30 cm, 60 x 45 cm, 60 x 60 cm according to different treatment combinations. All the management practices including hoeing: weeding and other horticultural operation were performed. Observations on yield per plant (kg), yield per harvesting (t/ha), individual fruit weight (g), length of fruit (cm),fruit breadth (cm), unmarketable fruit yield per plant (kg), marketable yield per plant (kg), marketable yield per hectare (t/ha), total yield (t/ha) was recorded from five randomly selected plants of each replication.

Results and Discussions

The plant spacing significantly influenced yield and quality parameters in capsicum. Data (Table-1) revealed that maximum yield per harvesting (9.68), maximum marketable yield per hectare (55.09 t/ha), maximum total yield per hectare (55.43 t/ha) was observed with closer spacing S_1 (60 x 30 cm) as compared to medium (60 x 45 cm) and wider (60 x 60 cm) spacing. These results are in similar with the findings of Zende (2008) [8]. These might be due to the increase in plant population was lead to increase in maximum yield per harvesting which ultimately results in maximum marketable yield and total yield. Minimum unmarketable yield per plant (0.04 kg) which might be due to less number of flowers, fruits and minimum extent of fruit set. The results are in accordance with Ahirwar and Hedau (2015) [1] in capsicum. Maximum yield per plant (1.96 kg), highest individual fruit weight (115.87 g), maximum fruit breadth (8.00 cm), maximum fruit length (10.47 cm) was noticed in wider spacing S_3 (60 x 60 cm). These might be due to the reason that wider spacing facilitated the plant to develop more rapidly with less inter and intra plant competition for utilizing the available resources from soil and aerial space resulting increase in size of fruit (length and breadth) ultimately resulted in increased fruit weight and higher yield per plant. These results are in conformity with the findings of Islam *et al.* (2011) [4]. Maximum marketable yield per plant (1.82 kg) was recorded in wider spacing S3 (60 x 60 cm). The results are in accordance with Ahirwar and Headau (2015) [1] and Alam (2016) [2] in capsicum.

Table 1: Effect of spacing and training on growth and reproductive parameters of capsicum.

Particulars	Characters									
	Plant height (cm)	No. of leaves	Leaf area (cm^2)	Days for flower initiation	Days taken for 50 % flowering	Days taken for fruit set	No. of flowers	No. of fruits	Percent fruit set (%)	Days taken for first harvesting
Main effect of spacing (S)										
S_1 (60 x 30 cm)	74.38	61.61	54.63	54.64	68.44	58.33	10.09	8.78	73.49	69.57
S_2 (60 x 45 cm)	80.87	83.61	48.34	42.30	57.40	46.96	14.80	12.15	79.09	58.60
S_3 (60 x 60 cm)	83.07	95.61	41.92	32.11	46.22	36.77	18.86	16.50	83.53	48.11
SE ±	0.63	1.52	0.88	1.04	1.19	0.97	0.34	0.29	1.39	0.96
CD @ 5 %	1.90	4.52	2.63	3.12	3.57	2.93	1.02	0.89	4.18	2.89
Main effect of training levels (T)										
T_1 (two shoots)	85.01	78.17	42.93	37.05	51.13	41.76	13.25	9.79	69.04	53.20
T_2 (three shoots)	79.65	92.39	51.54	42.27	55.13	46.98	13.75	12.32	82.07	58.37
T_3 (four shoots)	73.65	103.28	50.42	54.64	65.80	53.32	17.63	15.32	85.00	64.71
SE ±	0.63	1.52	0.88	1.04	1.19	0.97	0.34	0.29	1.39	0.96
CD @ 5 %	1.90	4.56	2.63	3.12	3.57	2.93	1.02	0.89	4.18	2.89
Interaction effect of spacing and training (S x T)										
S_1T_1	82.21	61.61	49.20	47.20	63.33	52.00	8.72	5.67	56.19	63.33
S_1T_2	77.24	83.61	61.10	50.20	60.66	55.00	11.10	9.34	80.51	66.20
S_1T_3	63.68	95.61	53.60	66.53	81.33	68.00	13.10	11.34	83.76	79.20
S_2T_1	85.39	81.43	46.20	39.30	53.40	43.96	13.46	10.20	72.72	55.60
S_2T_2	80.31	93.43	48.33	42.30	57.40	46.96	14.46	12.13	81.20	58.60
S_2T_3	76.91	95.43	50.50	45.30	61.40	49.96	16.46	14.13	83.35	61.60
S_3T_1	87.43	91.46	33.40	24.66	36.66	29.00	17.56	13.50	78.23	40.66
S_3T_2	81.41	100.13	45.20	34.33	47.33	39.00	15.70	15.50	84.49	50.33
S_3T_3	80.37	118.80	47.16	37.33	54.66	42.00	23.33	20.50	87.89	53.33
SE ±	1.09	2.63	1.52	1.80	2.06	1.69	0.59	0.51	2.41	1.67
CD @ 5 %	3.29	7.89	4.56	5.40	6.19	5.07	1.77	1.54	7.24	5.01

Among the methods of training, highest individual fruit weight (115.92 g) was recorded in T_2 (two shoots), the present investigation is in conformity with the findings of Cebula (1995) [3] in capsicum. Maximum fruit breadth (8.40 cm), maximum fruit length (10.81 cm) was recorded with training T_1 (two shoots). The similar results were recorded by Lal *et al*. (2014) [6]. Minimum unmarketable fruit yield per plant (0.04 kg), was recorded with training T_1 (two shoots). These might be due to less number of shoots per plant. Highest marketable yield per plant (1.20 kg) was recorded with T_2 (three shoots) training. The maximum yield per plant (1.84 kg), maximum yield per harvesting (10.64 t/ha), marketable yield per hectare (61.94 t/ha), total yield (63.97 t/ha) was recorded with training T_3 (four shoots). This might be due to more number of shoots per plant and having more fruit bearing area. The similar results were found and recorded by Ahirwar and Hedau (2015) [1].

Among all the treatment combinations, S_1T_1 (60 x 30 cm and two shoots) recorded lowest unmarketable fruit yield per plant (0.02 kg). The results are supported by Ahirwar and Headau

(2015) [1]. S_1T_3 (60 x 30 cm and four shoots) recorded highest yield per harvesting (13.41), highest total yield (78.88 t/ha), Marketable yield per hectare (77.77 t/ha). The results are in accordance with the findings of Moboko *et al*. (2011) [7]. The treatment combination S_3T_1 (60 x 60 cm and two shoots) recorded highest individual fruit weight (137.07 g), maximum fruit length (12.13 cm) and maximum fruit breadth (8.80 cm) this is because at the wider spacing and low shoot density the competition for the nutrient and light among the plants and within the plant is low as compared to that of high plant and shoot spacing. The results are in accordance with the findings of Lal *et al*. (2014) [6]. Maximum yield per plant (2.78 kg) and highest marketable yield per plant (2.54 kg) was recorded with the treatment combination S_3T_3 (60 x 60 cm and four shoots).

Conclusion

From the present investigation it can be concluded that the combination S_1T_3 (60 x 60 cm and four shoots) was found superior over all the other treatments in terms of economic characters such as yield per harvesting, marketable yield per hectare and total yield per hectare, which is an ultimate goal of any experiment.

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