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Analysis of bell pepper (*Capsicum annuum*) cultivation in response to fertigation and training systems under protected environment

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ABSTRACT

The experiment was carried out to standardize fertigation and training system for bell pepper (*Capsicum annuum* L.) cultivation under protected conditions during 2013-14, 2014-15, 2015-16 involving 4 levels of fertilizer [F_1-300:300:300 kg/ha (RDF through conventional method), F_2-300:300:300 kg/ha (Fertigation), F_3-250:250:250 kg/ha (Fertigation), F_4-350: 350: 350 kg/ha (Fertigation)] and 3 training systems (P_1-Two shoot system, P_2-Three, P_3-Four). The results revealed significant effect on plant height and fruit length due to main effect of fertilizers recording maximum values for the traits in F_4 level. F_3 level of fertilizers contributed towards earliness and maximum fruit diameter (7.31 cm), pericarp thickness (0.70 cm), fruit weight (150.40 g), fruit volume (236.31 cc), number of fruits (20.78), yield per plant (3.11 kg) and yield per 1000 m^2 (8.90 t). P_1 level of training system excelled all other training systems exhibiting maximum plant height during different periodical observations at 30, 60, 90 and 120 days after planting (DAP). The plants trained to P_3 level were observed to earliest in flowering as well as picking and produced significantly maximum number of fruits (21.09), fruit yield per plant (2.62 kg) and yield per 1000 m^2 (7.99 t). P_1 training system showed significant effect on various fruit parameters and recorded maximum fruit length, diameter, pericarp thickness, fruit weight, fruit volume, shelf life. Treatment combination F_4P_1 displayed significantly maximum plant height of 147.34 cm at 90 DAP. Bell pepper plants fertigated with F_3 level and trained to P_3 system (F_3P_3) recorded maximum number of fruits per plant (25.79), fruit yield per plant (3.63) and fruit yield per 1000 m^2 (10.74) thereby revealing higher net returns of ₹ 168621 with BCR of 1.10 for bell pepper.

Keywords: Bell pepper, Economics, Fertigation, Horticultural traits, Polyhouse, Training systems

Bell pepper (C*apsicum annuum* L.) has attained a status of high value crop in recent years and occupies a pride place among vegetables in Indian cuisine because of its delicacy and pleasant flavour coupled with rich content of ascorbic acid and other vitamins, minerals etc. The bioactive components of capsicum work together improving blood flow, as a cancer preventive, an analgesic, protecting the gastric mucosa, and providing necessary nutrients beneficial to a healthy lifestyle (Clement *et al*. 2012). The cultivation of bell pepper in India has picked up because of recent interest due to high demand for fast food dishes in hotels and modern restaurants. However, the crops grown in open field are often exposed to fluctuating levels of temperature, humidity, wind flow etc. due to uncertain behaviour of weather, which ultimately affect the crop productivity adversely. Hence, the greenhouse system makes it possible to avoid the excessive deviation of the temperature inside the greenhouse and provides a favourable microclimate for the precocity of the culture (Omer 2016). In modern agriculture, green house technology can be utilized for control of environmental parameters such as temperature, relative humidity, light intensity, light duration, CO_2 level, irrigation, nutrient supply and uptake, spacing, growing medium and root development (Baghel *et al*. 2003). These structures also facilitate the utilization of nutrients from soil for longer duration (Singh *et al*. 2005).

The fertigation in any crop plays a vital role in deciding the production and ultimately productivity. The fertigation through drip irrigation allows applying nutrients precisely and uniformly to the rhizosphere, thus increases the efficiency of fertilizers (Locascio 2005). Pruning of the capsicum plants to two stem, three or four stem not only facilitate easy training operation but also permit closer planting, early ripening of fruits and ultimately higher yields of larger sized fruits (Dasgan and Kazim 2003, Alam 2016, Awalin *et al*. 2017). With the above perspectives, a study on the influence of fertigation and training system in bell pepper was taken up for three years to draw conclusive inferences.

MATERIALS AND METHODS

The experiment was conducted during the month of October in all consecutive years of study (2013-14, 2014-

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Table 1 Physico-chemical properties of water and growing media

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
EC_{Water} (dS/m)	0.70	EC_{Soil} (dS/m)	1.43	Organic Carbon (%)	0.61	Available P (kg)	27.15
pH_{Water}	7.30	pH_{Soil}	6.40	Available N (kg)	275.98	Available K (kg)	301.23

15 and 2015-16) in bell pepper cv. Indra under naturally ventilated polyhouse of 2000 m^2 (NVPH) at Regional Horticultural Research Station, Navsari Agricultural University, Navsari (Gujarat), India which is positioned at latitude of 20°57'N and longitude of 72°54'E with an altitude of only 12 m amsl. The growing media used for the experiment proportionally composed of 70% red soil: 30% FYM, which was subjected to sterilization with formaldehyde (1: 10) prior to planting. The physico-chemical analysis of growing media as well as water quality is given in Table 1.

The experiment involved 12 treatments with 4 levels of fertilizers [F_1- 300:300:300 kg/ha (RDF through conventional method), F_2-300:300:300 kg/ha (Fertigation), F_3- 250:250:250 kg/ha (Fertigation), F_4-350: 350: 350 kg/ha (Fertigation)] and 3 training systems [P_1-Two shoot system, P_2-Three, P_3-Four] with common application of 5 kg *Trichoderma viride*, phosphorous solubilizing bacteria (*Bacillus megaterium*), *Azotobactor*, *Pseudomonas fluorescens* each, 4 t vermicompost and 50 kg micro-nutrients (Grade-5) at the time of planting. In case of conventional method of fertilizer application, full dose of phosphorous and potassium and half dose of nitrogen were applied at the time of planting and remaining half of N in three splits at 30, 60 and 90 days after planting. The distribution pattern as per ratio of nutrients was followed in fertigation treatments (Table 2).

Pinching of apical bud was carried after 20 to 25 days of planting, which resulted in emergence of many side shoots from axial of leaves. These side shoots were allowed to grow upto 8-10 cm length and then weaker ones were pruned by retaining two, three and four stronger shoots in two, three and four system stem, respectively. As tip of bell pepper plant at every node splits into two branches giving rise to one strong and one weak branch, so weaker one was removed periodically at weekly interval in each training system. The retained stronger shoots were trained upon strings to the main overhead wire.

Table 2 Distribution pattern of nutrients applied through fertigation.

Crop duration	Distribution ratio of nutrients			Time of fertigation initiation	Fertigation frequency
	N	P	K		
1st Growth period (Up to 30 days)	2	3	1	10-15 days of planting	Once a week
2nd Growth period (31-60 days)	1	2	2		
3rd Growth period (61-90 days)	1	1	3		
4th Growth period (91-120 days)	1	1	2		
5th Growth period (121-150 days)	1	1	1		
6th Growth period (15-180 days)	1	1	1		

The experiment was laid out in a Randomized Complete Block Design (Factorial concept) with three replicates on raised beds having dimensions of 100 × 40 × 50 cm (width, height and distance between two beds) with plot size of 4.5 × 7.2 m. The crop was spaced at 45 × 30 cm distance occupying 96 plants and 56 plants in gross lot and net plot, respectively. The data on various parameters *viz.* days to first flowering, days to first picking, plant height (cm) at 30, 60, 90, 120 days after planting (DAP), fruit length (cm), fruit diameter (cm), pericarp thickness (cm), average fruit weight (g), fruit volume (cc), shelf life (days), number of fruits per plant, yield per plant (kg) and yield per 1000 m^2 (t) were recorded and the mean values were subjected to statistical analysis as per Panse and Sukhatme (1985).

The economic analysis of bell pepper cultivation was carried out through an accounting method as suggested by Berry *et al*. (1979) and Gittinger (1982). The actual values on fixed investment were subjected to amortized accounting by adopting certain assumptions as under:

Particular	Useful life (yrs)	Remarks
Polyhouse Structure	10	*Conditional life of red soil has been considered equivalent to that of structure's life assuming that sufficient organic matter will be incorporated into it over the period of time.
Red soil*	10	
Plant support system	5	

The prevailing market price during the cropping period was accounted into analysis of variable components. The labour wages were established as per the notification of Assistant Labour Commission and Minimum Wages Act, Gandhinagar, Government of Gujarat State, India (Anonymous 2016).

RESULTS AND DISCUSSION

Main effect of fertilizer

The pooled data on various growth, reproductive and fruit parameters indicated significant differences for majority of traits due to main effect of fertilizers and training systems (Table 3). Different level of fertilizers revealed non-significant differences for plant height at 30 DAP. Nevertheless, bell pepper plants responded to

Table 3 Main effects of fertigation and training systems on growth, reproductive and fruit parameters of bell pepper in polyhouse conditions (Pooled mean of 3 seasons)

Treatment	Days to first flowering	Days to first picking	Plant height (cm) 30 DAP	Plant height (cm) 60 DAP	Plant height (cm) 120 DAP	Fruit length (cm)	Fruit diameter (cm)	Pericarp thickness (cm)	Average fruit wt. (g)	Fruit volume (cc)	Shelf life (days)
F_1	44.30	78.28	51.00	76.87	128.65	5.88	5.39	0.54	95.11	150.22	7.45
F_2	41.53	72.07	48.85	88.10	164.59	7.72	6.95	0.68	141.14	221.31	8.41
F_3	39.56	69.93	48.59	85.78	160.79	7.60	7.31	0.70	150.40	236.31	8.39
F_4	47.35	78.52	50.85	92.22	169.74	7.91	6.56	0.61	129.46	203.22	7.56
$LSD_{0.05}$	2.22	3.09	NS	3.56	7.79	0.27	0.28	0.09	14.09	18.65	0.27
P_1	45.91	77.93	51.86	90.24	165.02	7.99	6.99	0.69	141.13	221.31	8.28
P_2	42.69	74.61	50.25	86.08	155.92	7.17	6.54	0.62	126.34	198.52	7.86
P_3	40.96	71.56	47.36	80.91	146.89	6.68	6.13	0.59	119.62	188.46	7.72
$LSD_{0.05}$	1.96	2.71	1.96	3.14	6.82	0.24	0.24	0.04	4.54	6.98	0.24
F × P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

exert significant effect on plant height from 60 days of planting onwards and the plants fertigated with F_4 level showed significantly maximum plant height of 92.22 cm and 130.74 cm, respectively at 60 and 90 days of planting (Table 3 and 4). Bell pepper plants responded similarly for the trait after 120 days of planting and recorded maximum plant height (169.74 cm) in F_4 level of fertilizers with statistically similar results in F_2 level. This kind of response in plant growth could be accreditated to enhanced effects of NPK on vegetative parameters of plant species (Marschner 1995). The present results also corroborate with the findings of earlier researchers (Xu *et al*. 2001, Bowen 2002, Rwiza and Kisetu 2014) who also highlighted the role of NPK levels on enhanced vegetative growth in bell pepper.

The data on reproductive parameters revealed earliness for flowering (39.56 days) in plants fertigated with F_3 level of fertilizers, which was statistically at par with F_2 level of fertilizers. Earliness in flowering corresponded positively to early picking, therefore, F_3 also responded significantly to early picking with at par performance in plants raised in F_2 level of fertilizers (Table 3). Goh and Haynes (1986) and Salisbury and Ross (1991) also revealed the impact of fertigation on synthesis of various metabolic intermediates leading to reproductive earliness.

Fruits produced under F_4 level of fertilizers showed maximum fruit length, which was statistically at par with fruit length displayed in F_2 level. Whereas in case of fruit diameter, F_3 level of fertilizers showed significantly maximum fruit diameter of 7.31 cm. Similarly, F_3 also exhibited maximum pericarp thickness of 0.70 cm, which was having statistically similar performance in plants fertigated with F_2 and F_4 levels of fertilizer. F_3 level of fertilizer recorded maximum fruit weight of 150.40 g in bell pepper, which was at par with F_2 level of fertilizer. As fruit weight had proportionate contribution to influence its volume, so similar trend was observed for fruit volume displaying maximum fruit volume of 236.31 cc in F_3 level of fertilizers. Fruits produced under F_2 level of fertilizers recorded maximum shelf-life of 8.41 days which was at par with results under F_3 level of fertilizers (Table 3). The results also connoted significantly maximum number of fruits (20.78) in plants fertigated F_3 level of fertilizers. Correspondently, F_3 level of fertilizers expressed higher yield per plant (3.11 kg) with at par performance in F_2 level. Nonetheless, fruit yield per 1000 m^2 was observed to be significantly maximum (8.90 t) in F_3 level of fertilizers (Table 4). Xu *et al*. (2001), Bowen (2002) and Rwiza and Kisetu (2014) in capsicum and El Sanafawi *et al*. (2006) in cucumber presented strong relationships among various fruit parameters and their contribution towards higher yield per unit area as a result of positive effect of fertigation.

Main effect of training system

Bell pepper plants trained to P_1 level of training system showed maximum plant height (51.86 cm) at 30 DAP, which was statistically at par with P_2 level of training system. The plants trained to two stem system (P_1) excelled all other training systems significantly for plant height at 60, 90 and 120 days with the levels of 90.24 cm, 130.74 cm and 165.02 cm, respectively (Table 3 and 4). The results were in accordance with the findings of Dasgan and Abak (2003), Ahirwar and Hedau (2015) and Awalin *et al*. (2017) in capsicum and Alam *et al*. (2016) in tomato observed similar kind response for growth characteristics.

Bell pepper plants trained to four shoot system (P_3) displayed earliest flowering taking only 40.96 days for first flowering, which was statistically at par with plants trained to three shoot system (P_2). However, this training system excelled all other levels of training system significantly for earliness in picking by taking 71.56 days (Table 3). Alam *et al*. (2016) and Awalin *et al*. (2017) also observed positive effect of stem pruning on early picking in tomato and bell pepper, respectively.

The plants trained to two stem system (P_1) produced

Table 4 Interaction effect of fertigation and training systems on plant height, number of fruits per plant and fruit yield of bell pepper in polyhouse conditions (Pooled mean of 3 seasons)

Treatment	Plant height at 90 DAP				Number of fruits per plant				Yield per plant (kg)				Yield per 1000 m^2 (t)			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
F_1	103.50	100.42	101.14	101.69	11.35	14.18	15.17	13.57	1.30	1.22	1.26	1.26	3.32	3.35	3.85	3.50
F_2	133.81	121.38	111.13	122.11	15.91	17.81	25.32	19.68	2.46	2.44	3.42	2.77	7.16	7.49	10.14	8.26
F_3	133.75	119.56	108.80	120.71	17.70	18.85	25.79	20.78	2.84	2.86	3.63	3.11	7.87	8.09	10.74	8.90
F_4	147.34	131.74	113.14	130.74	13.40	16.17	18.07	15.88	1.87	2.11	2.16	2.05	5.97	7.06	7.22	6.75
Mean	129.60	118.28	108.55		14.59	16.75	21.09		2.12	2.16	2.62		6.08	6.50	7.99	
		LSD$_{0.05}$				*LSD$_{0.05}$*				*LSD$_{0.05}$*				*LSD$_{0.05}$*		
F		4.76				1.03				0.37				0.53		
P		4.19				0.91				0.13				0.45		
F × P		7.89				1.72				0.25						

(All other interactions F × Y, P × Y and F × P × Y were found to be non-significant.

fruits with significantly maximum fruit length (7.91 cm), diameter (6.99 cm) and pericarp thickness (0.69 cm) along with significantly maximum fruit weight (141.13 g), fruit volume (221.33 cc) and shelf-life (8.28 days) (Table 3). However, plants trained to four shoot system produced significantly maximum number of fruits, fruit yield per plant as well as per 1000 m^2 to the tune of 21.09, 2.62 kg and 7.99 kg, respectively over remaining levels of training system (Table 4). Cavero *et al*. (2001), Dasgan and Abak (2003), Manohar Lal *at el*. (2014), Ahirwar and Hedau (2015) and Awalin *et al*. (2017) had also reported higher yield and inter-relationships of yield parameters in capsicum, whereas Cordt (1999) and Alam *et al*. (2016) noticed positive impact of training system on yield and other related traits in tomato.

Interaction effect of fertilizers and training systems

The pooled data demonstrated significant interaction effect of fertilizers and training systems on plant height at 90 DAP, number of fruits per plant, fruit yield per plant as well as per 1000 m^2 (Table 4).

Treatment combination F_4P_1 registered significantly maximum plant height of 147.34 cm. Bell pepper plants administered with F_3 level of fertilizer and trained to P_3 level of training system recorded maximum number of fruits (25.79) as well as fruit yield per plant (3.63 kg), which was statistically at par with treatment combination F_2P_3. However, F_3P_3 combination outyielded all other treatment combinations significantly recording 10.74 t fruit yield per 1000 m^2. Xu *et al*. (2001), Bowen (2002), Tiwari *et al*. (2013), Rwiza and Kisetu (2014) in capsicum and Kavitha *et al*. (2007) in tomato also accentuated the importance of fertigation on yield and related traits. Similar response of training system was also observed by Cavero *et al*. (2001), Dasgan and Abak (2003) and Awalin *et al*. (2017) in capsicum and Cordt (1999) and Alam *et al*. (2016) in tomato.

Economic analysis

As protected cultivation is highly capital intensive farming requiring substantial investment during the initial period of establishment, so investment on fixed components namely naturally ventilated polyhouse, red soil and plant support system in the present study was worked out to be ₹ 59908 for a single season. The analysis of production system of bell pepper under NVPH displayed total cost of cultivation ranging from ₹ 132200 to 157266 invariably dependent on labour involvement and quantity of training strings in training systems, cost of fertilizers and packing of produce in respective treatments. It is evident from the study that bell pepper plants fertigated with F_3 level of fertilizers and trained to four shoot system (P_3) showed highest yield per unit area thereby revealing highest net returns of ₹ 168621.00 with BCR of 1.10 (Table 5). Jovicich *et al*. (2005), Singh *et al*. (2005) and Sreedhara *et al*. (2013) were also of the view that protected cultivation provides more remuneration on account of 3 to 4 times higher and better quality yield.

Table 5 Economic analysis of bell pepper cultivation under the influence of combined effect of fertigation and training systems in polyhouse conditions (Pooled analysis)

Treatment	Amortized fixed cost for a single season (₹)	Variable cost (₹)	Total cost of cultivation (₹)	Gross returns (₹)	Net realization (₹)	BCR
F_1P_1	59908	72292	132200	99600	-32600	-0.25
F_1P_2	59908	76206	136114	100500	-35614	-0.26
F_1P_3	59908	83164	143072	115500	-27572	-0.19
F_2P_1	59908	84348	144256	214800	70544	0.49
F_2P_2	59908	88330	148238	224700	76462	0.52
F_2P_3	59908	95781	155689	304200	148511	0.95
F_3P_1	59908	82264	142172	236100	93928	0.66
F_3P_2	59908	86222	146130	242700	96570	0.66
F_3P_3	59908	93671	153579	322200	168621	1.10
F_4P_1	59908	86323	146231	179100	32869	0.22
F_4P_2	59908	90479	150387	211800	61413	0.41
F_4P_3	59908	97358	157266	216600	59334	0.38

It is therefore concluded from the study that bell pepper growers could get higher yield and better net returns through fertigation @ 25: 25: 25 kg NPK per 1000 m^2 (As per the fertigation schedule given in Table 2) and training plants to four shoot system along with application of 0.5 kg *Trichoderma viride*, phosphorous solubilizing bacteria (*Bacillus megaterium*), Azotobactor, *Pseudomonas fluorescens* each, 0.4t vermicompost and 5.0 kg micro-nutrients (Grade-5) at the time of planting.

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