Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(3): 3386-3390
Received: 19-03-2019
Accepted: 21-04-2019

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Influence of growing media and plant spacing on coloured capsicum under naturally ventilated polyhouse

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Abstract
An experiment was conducted in naturally ventilated polyhouse at Vegetable Research Farm of Department of Vegetable Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, during 2015 and 2016 to find out the most suitable growing media and plant spacing for quality and growth of the capsicum. Data with regards to interaction effect revealed that the growing media Soil + Cocopeat + Vermicompost + FYM (2:1:0.5:0.5) with plant spacings 45×60 cm resulted the maximum total carotenoids (2.10%), ascorbic acid (122.23%) and total soluble solid (7.08 °B) while minimum was recorded under Soil + Sand + FYM (2:1:1) with plant spacing 45×30 cm (1.86%, 117.03%, 6.28 °B). The result revealed that among various treatment combinations growing media Soil + Cocopeat + Vermicompost + FYM (2:1:0.5:0.5) with plant spacing 45×60 cm recorded maximum leaf area index (3.23), net assimilation rate (0.083 mg/leaf area/day) and plant biomass (150.36 g/plant) and). Therefore it can be inferred that incorporation of Soil, Cocopeat, Vermicompost, and FYM with appropriate crop spacing led to the better quality and growth of capsicum.

Keywords: Plant spacing, capsicum, growing media

Introduction
Capsicum (*Capsicum annuum* L. var. grossum) also called as bell pepper, sweet pepper, green pepper or *Shimla mirch* is highly remunerative crop for protected cultivation. India contributes one fourth of world production of capsicum with an average annual production of 0.9 million tons from an area of 0.885 million hectare (Sreedhara *et al.*, 2013) [38]. Due to erratic behaviour of weather, the crops grown in open field are often exposed to fluctuating levels of temperature, humidity, wind flow *etc*. which ultimately affect the crop productivity adversely (Ochigbo and Harris, 1989) [26]. To obtain good quality produce and production during off season there is need to cultivate capsicum under protected conditions such as greenhouse or polyhouses especially under mid hill zone of Himachal Pradesh. Growing of vegetables under poly house improves quality of produce this in turn is helpful in getting higher price that becomes remunerative to grower (Navale *et al*., 2003) [24]. Its yield in open field condition ranges from 30-40 t ha-1 where as in greenhouse it is 100-120 t ha-1 (Prabhakar *et al*., 2004) [27]. Capsicum is an important vegetable from nutrition point of view especially it's colored varieties, but under open field condition only green color varieties with one season can be grown. So its year round production especially of colored varieties will be a boon to the growers of this tiny hill state (Gupta *et al.,* 2016) [11]. Plant population has a pronounced influence on plant development, growth and marketable yields of any vegetable crop. The plant spatial arrangement is one of the crop management practice that has been used to increase yield of sweet pepper per unit area in greenhouse (Cebula, 1995) [4]. Crop spatial arrangement has immense effect on all the growth and yield characters. Proper spacing results in higher yield (Llaven *et al*. 2008) [17]. There is a direct relationship between spacing of crop on yield attributing characters such as number of branches, number of fruits, fruit size and yield etc. The closer spacing in general results in higher yield but reduces fruit size. It also has a marked influence on the quality characters of the fruit and seed (Mantur *et al*. 2005) [21].
Keeping this in view, an experiment was conducted to standardize the agro techniques which influence capsicum production in the naturally ventilated polyhouse. The important components affecting productivity and quality of produce inside polyhouse are growing media and plant spacing which were arranged in 12 treatment combinations. The consistent and discriminate use of inorganic fertilizers have caused serious damage to soil health, ecology and caused decline in vitamin and mineral content of fresh fruits and vegetables. The addition of farm organic wastes, manures, cocopeat and vermicompost etc. are extremely important to maintain the fertility and productivity of the agricultural system.

Organically grown greenhouse crops in general, have higher nutrient demands than field grown crops and therefore, in order to optimize production it is essential to focus on the growing media studies (Tariq *et al.*, 2016) [40].

Material and Methods

An experiment to study the effect of different growing media, and plant spacing on capsicum (bell pepper) production in the naturally ventilated polyhouse in the mid hills of India during February, 2015 and 2016 was conducted at Vegetable Research Farm, Department of Vegetable Crops, Dr. Y.S Parmar University of Horticulture and Forestry, Nauni- Solan, India. A naturally ventilated polyhouse having 20 m length and 6 m width already constructed at the farm was used for laying out experiment on F1 hybrid cultivar Orobelle. The experiment was laid out in a randomized block design (Factorial) with three replications in a plot size of 0.9 x 1.8 m with four different growing media (M) *viz*., (M1) Soil + Sand + FYM (2:1:1), (M2) Soil + Cocopeat + FYM (2:1:1), (M3) Soil + Cocopeat + Vermicompost (2:1:1), (M4) Soil + Cocopeat + Vermicompost + FYM (2:1:0.5:0.5) and three plant spacings with different population (S) *viz*., 45×30 cm (S1), 45×45 cm (S2), and 45×60 cm (S3). Twelve different Treatment combinations *viz*., M1S1, M1S2, M1S3, M2S1, M2S2, M2S3, M3S1, M3S2, M3S3, M4S1, M4S2, M4S3 were transplanted in the polyhouse. Treatment details along with symbols are depicted in Table-1. The observations were recorded on quality parameters *viz*., Total carotenoids and ascorbic acid content calculated as per the method suggested by Ranganna (2009) [30], pericarp thickness (Measurements were done with Digital Vernier Calliper), total soluble solid and growth parameters *viz*., Leaf area index (Redford, 1967) [31], net assimilation rate (Noggle and Fritz, 1976) [25] and plant biomass. The data recorded were analyzed through ANOVA for RBD (Factorial) experiments. The results have been interpreted on the basis of 'F' test and critical difference (CD) at 5% level of significance.

Result and discussion

Quality parameters

Maximum values for total carotenoids (2.10%), ascorbic acid (122.23%), pericarp thickness (8.36 mm), total soluble solid (7.08 °B), were recorded in M4 over other growing media during both the years of experimentation as depicted in Table-1. The media M3 performed closely behind it and gave the second best results and many times was statistically at par to the highest readings. Organic growing media have a property of good water holding capacity and are also able to drain excess water to come to field capacity which creates congenial root environment.Soil, cocopeat, vermicompost and FYM as a growing medium and optimum plant spacing of 45 x 45 cm as plant spacing have been observed to increase the amount of vitamin C in the experiment. The lowest vitamin C values were determined in the growing media comprising of soil, sand, FYM and 45 x 30 cm plant spacing. These result showed that growing medium in addition to plant spacing also could affect vitamin C content. The treatments might have helped in the nitrogen fixation besides providing higher root biomass and release of nutrients slowly so that they are taken by the crop for synthesis of useful biochemical component. Improvement in ascorbic acid content in sweet pepper fruits by the application of this treatment combination may be because of slow but continuous supply of the entire macro and micro nutrients which might have helped the assimilation of carbohydrates resulting into synthesis of ascorbic acid (Bahadur *et al.*, 2005) [2]. Similar are the findings of Jaipaul *et al.* (2011) [13]. Laxmi *et al.* (2015) [16] also reported increase in ascorbic acid and other quality parameters which they attributed to increased availability of major and minor nutrients specially N and K as they play a vital role in enhancing the fruit quality. The pepper fruit color is determined by both the amount and composition of the carotenoides that have accumulated in the chromoplast. Total carotenoid content is one of the major quality components in sweet pepper (Ram, 1998) [29].

High total carotenoid content in addition to improving the nutrition also helps in better retention of natural color and flavour of sweet pepper. The variation of total carotenoides was found significant amongst the different growing media with the different plant spacing. The quality of fruits in sweet pepper with respect to color and nutrient were also influenced by the sources of nutrient used for their production as evidenced from the results of the present studies. The temperature, moisture capacity, aeration etc of growing media coupled with optimum plant density can affect especially root growth, water and mineral uptake with less plant competition. cocopeat, vermicompost and FYM as a growing medium quickly heat up and cool down, are good media in regard to drainage and aeration. It was reported that water holding capacity of this growing medium is better than soil, sand and FYM based growing medium. These factors can affect the growth, yield and quality of pepper. Our results were similar to that of Abu Zahra (2011) [1], Fawzy *et al.* (2012) [8], Kumari *et al.* (2009) [15] and Rajbir Singh *et al*. (2008) [28], who also observed similar results in bell pepper. Pericarp thickness directly relates to the keeping quality of fruits with more shelf life under ordinary conditions. It is also useful for transportation of pepper fruit to distant markets. It is a very important parameter for better texture, capsicum is used as a salad crop so more pericarp thickness will provide the better quality salad. TSS signifies the amount of sugar and other soluble compound present in the fruit juice. High total soluble solids are desirable for processed products.

Table 1: Total Carotenoid (mg/100 g), Ascorbic acid (mg/100g), Pericarp thickness (mm and Total soluble solid (ºB), as influenced by growing media, plant spacing and their interaction

Treatments	Total Carotenoid (mg/100 g)			Ascorbic acid (mg/100g)			Pericarp thickness (mm)			Total soluble solid (ºB)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
M_1	1.91	1.85	1.88	119.06	117.06	118.06	7.18	7.01	7.10	6.42	6.34	6.38
M_2	1.92	1.91	1.91	121.27	119.20	120.24	7.85	7.64	7.74	6.75	6.71	6.73
M_3	2.07	2.04	2.06	122.38	120.80	121.59	8.40	8.13	8.27	7.04	6.97	7.01
M_4	2.13	2.08	2.10	122.85	121.60	122.23	8.44	8.28	8.36	7.09	7.07	7.08
Mean	2.01	1.97	1.99	121.39	119.67	120.53	7.97	7.76	7.87	6.83	6.77	6.80
$CD_{0.05}$	0.06	0.06	0.06	1.34	0.95	1.16	0.13	0.17	0.15	0.05	0.18	0.13
S_1	1.97	1.93	1.95	120.39	118.53	119.46	7.77	7.46	7.61	6.77	6.69	6.73
S_2	2.04	2.01	2.02	122.01	120.35	121.18	8.04	7.81	7.93	6.87	6.85	6.86

S_3	2.01	1.98	1.99	121.78	120.12	120.95	8.09	8.02	8.06	6.84	6.78	6.81
Mean	2.01	1.97	1.99	121.39	119.67	120.53	7.97	7.76	7.87	6.83	6.77	6.80
$CD_{0.05}$	0.05	0.05	0.05	1.16	0.82	1.01	0.11	0.14	0.13	0.04	NS	0.11
M_1S_1	1.90	1.83	1.86	118.15	115.92	117.03	6.95	6.71	6.83	6.32	6.24	6.28
M_1S_2	1.93	1.88	1.90	120.04	118.25	119.15	7.43	7.08	7.26	6.38	6.37	6.38
M_1S_3	1.89	1.85	1.87	119.00	117.00	118.00	7.17	7.25	7.21	6.56	6.42	6.49
M_2S_1	1.90	1.89	1.90	120.17	118.17	119.17	7.56	7.43	7.50	6.61	6.51	6.56
M_2S_2	1.96	1.93	1.94	121.93	119.61	120.77	7.93	7.58	7.75	6.89	6.86	6.87
M_2S_3	1.91	1.90	1.91	121.71	119.83	120.77	8.05	7.91	7.98	6.76	6.76	6.76
M_3S_1	2.02	1.98	2.00	121.30	119.25	120.28	8.38	7.66	8.02	7.08	6.95	7.02
M_3S_2	2.07	2.08	2.08	122.33	121.30	121.82	8.27	8.35	8.31	7.11	7.07	7.09
M_3S_3	2.12	2.07	2.09	123.51	121.85	122.68	8.55	8.39	8.47	6.94	6.89	6.92
M_4S_1	2.06	2.03	2.04	121.94	120.77	121.36	8.18	8.04	8.11	7.05	7.05	7.05
M_4S_2	2.19	2.13	2.16	123.72	122.22	122.97	8.53	8.25	8.39	7.12	7.10	7.11
M_4S_3	2.13	2.09	2.11	122.90	121.82	122.36	8.60	8.55	8.58	7.10	7.04	7.07
Mean	2.01	1.97	1.99	121.39	119.67	120.53	7.97	7.76	7.87	6.83	6.77	6.80
$CD_{0.05}$	NS	NS	NS	NS	NS	NS	0.22	NS	NS	0.08	NS	0.23

In the present findings, the TSS content increased with the application of cocopeat, vermicompost and FYM in soil with optimum plant population possibly because of higher content of metabolites in the fruits. This increase in TSS level of fruits may be due to increased availability of major as well as minor nutrients especially N and K in the treatment as they play a vital role in enhancing the fruit quality. Similar are the findings of Singh *et al.* (2010) [33]. The findings of Abu Zahra (2011) [1], Chetri *et al.* (2012) [5], Considering the results, it is noticed that growth characters of capsicum were increased with application of cocopeat, vermicompost and FYM. These results may be attributed to the role of macro and micro-nutrients, as well as the improved soil conditions due to vermicompost application, which conducted to stimulate metabolic processes and encourage growth, synthesis and accumulation of more metabolites in plant tissues. Several investigators mentioned similar results on different plants such as Kumar and Kohli (2005) [14] in capsicum, Natarajan (2005) [23] in tomato, Bairwa *et al* (2009) [3] in Okra. Optimum space availability between the plants might have increased the root spread which eventually utilized the resources such as water, nutrients, space and light very effectively Similar results were reported by Ganjare *et al.* (2013) [9], Malik *et al.* (2011) [20], Roy *et al.* (2011) [32], and Kumar (2011).

Growth parameters

Growth parameters found effected significantly by the growing media and plant spacing but the interaction effect of growing media and plant spacing were non-significant except incase of plant biomass as depicted in Table-2. Net assimilation rate of the plant increased significantly with the incorporation of cocopeat and vermicompost together in M3 media. M3 recorded the maximum value for net assimilation rate (0.084 mg/leaf area/day). The media M4, consisting of cocopeat, vermicompost and FYM recorded the maximum value for leaf area index (3.05) and plant biomass (149.03 g/plant), this increase may be due to better organic matter buildup, more translocation of the nutrients to aerial parts for synthesis of protoplasmic protein and other compounds (Singh *et al.*, 2000) [36], whereas M1 gave the poorest value during both the years. Incase of plant spacing the 45 x 60 cm obtained the maximum values for leaf area index (3.03),plant biomass (138.75 g/plant) and net assimilation rate (0.082 mg/leaf area/day). Leaf area index and net assimilation rate are an important variable in crop growth models, as it relates dry matter production to leaf area expansion and consequently to light interception and photosynthesis. According to Watson (1952) [41], the formation of optimum photosynthetic area and maintaining the leaf area in photosynthetically active stage for longer period were essential for increasing fruit yield. This is the main reason for the higher growth of morphological characters like plant growth, higher LAI and net assimilation rate under growing media M4 and M3 and plant spacing 45 x 60 cm as compared to the other treatments. Malawadi (2003) [19] observed greater leaf area index by the application of organic matter. This clearly indicates the importance of adding organic manures to the soil, which increases the availability of nutrients considerably resulting positive effect on growth parameters. Islam *et al.* (2011) [12] reported that wider spacing of crop ensures maximum number of leaves per plant and leaf area index. Stoffella and Bryan (1988) and Cebula (1995) [4] suggested that at a less plant density, plant efficiency would be increased by higher LAI and a high net assimilation rate in bell peppers. At a less plant density of the bell pepper, greater radiation interception due to higher LAI is resulted higher biomass and fruit yield (Lorenzo and Castilla 1995) [18]. Protected structure creates a favourable micro-environment by transmitting photosynthetically active solar radiations (400-700 nm) inside and with minimum difference in day and night temperature. Light intensity for better photosynthesis is also congenial inside the polyhouse (El-Aidy *et al.*, 1988) [7]. The present investigation also get support from Dasgan and Abak (2003) [6], who reported the similar result. Plant biomass is the dry weight of the plant after drying at a temperature of 60 ± 5oC for 72 hrs. Results showed an increase in plant biomass with vermicompost, cocopeat and FYM based growing media and wider palnt spacing. The results are in conformity with Arancon *et al.* (2005), Ghoname and Shafeek (2005) [10], Malik *et al.* (2011) [20], Narkhede *et al.* (2011) [22] and Rajbir Singh *et al.* (2008) [28], who noticed better growth and quality of the capsicum due to more availability of nutrients from the organic nutrient sources, indicating that vermicompost, cocopeat and FYM mineralized rapidly and provided optimum nutrients to the crop. The wider plant spacing leads to more growing area and better competition among plants and each plant was provided optimum nutrients and subsequently the better growth of the plant, which in turn had a positive effect on plant biomass.

The result of this investigation showed that the growing media Soil + Cocopeat + Vermicompost + FYM (2:1:0.5:0.5) at a plant spacing 45 x 60 cm and 45 x 45 cm gave highest quality and growth characters of capsicum cv. Orobelle. It can be attributed to the better soil structure created by organic growing media, both physically and biologically, along with the constant and steady nutrient supply to the plants. Apart from this, the proper spacing led to the healthy competition amongst the plants giving superior results and made the cultivation of capsicum in polyhouse less tedious and more economical as well.

Table 2: Leaf area index, Net assimilation rate (mg/leaf area/day) and Plant biomass (g/plant), as influenced by growing media, plant spacing and their interaction

Treatments	Leaf area index			Net assimilation rate (mg/leaf area/day)			Plant biomass (g/plant)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
M_1	2.77	2.68	2.73	0.070	0.080	0.075	123.28	112.08	117.68
M_2	2.90	2.83	2.86	0.072	0.087	0.080	133.61	118.81	126.21
M_3	3.09	2.99	3.04	0.079	0.089	0.084	153.88	139.51	146.69
M_4	2.98	3.11	3.05	0.076	0.086	0.081	157.14	140.93	149.03
Mean	2.93	2.90	2.92	0.074	0.085	0.080	129.56	107.14	118.35
$CD_{0.05}$	0.16	0.25	0.21	0.002	0.003	0.003	3.38	2.93	3.74
S_1	2.77	2.81	2.79	0.073	0.083	0.078	135.53	122.46	129.00
S_2	2.95	2.93	2.94	0.073	0.086	0.080	144.39	129.53	136.96
S_3	3.08	2.97	3.03	0.077	0.086	0.082	146.00	131.50	138.75
Mean	2.93	2.90	2.92	0.074	0.085	0.080	129.56	107.14	118.35
$CD_{0.05}$	0.14	NS	0.18	0.002	0.003	0.002	2.93	3.52	3.24
Interaction									
M_1S_1	2.71	2.64	2.68	0.067	0.078	0.073	116.15	108.06	112.11
M_1S_2	2.73	2.66	2.70	0.071	0.079	0.075	127.79	113.17	120.48
M_1S_3	2.86	2.74	2.80	0.073	0.081	0.077	125.90	115.02	120.46
M_2S_1	2.59	2.64	2.61	0.071	0.085	0.078	127.34	116.29	121.81
M_2S_2	2.96	2.91	2.93	0.068	0.088	0.078	133.11	119.05	126.08
M_2S_3	3.14	2.94	3.04	0.077	0.089	0.083	140.38	121.08	130.73
M_3S_1	2.95	2.86	2.91	0.079	0.086	0.083	142.57	126.83	134.70
M_3S_2	3.31	3.04	3.18	0.077	0.090	0.084	159.67	144.17	151.92
M_3S_3	3.02	3.08	3.05	0.080	0.092	0.086	159.40	147.52	153.46
M_4S_1	2.83	3.08	2.95	0.075	0.083	0.079	156.07	138.67	147.37
M_4S_2	2.80	3.12	2.96	0.076	0.087	0.082	157.00	141.75	149.38
M_4S_3	3.32	3.13	3.23	0.078	0.088	0.083	158.33	142.38	150.36
Mean	2.93	2.90	2.92	0.074	0.085	0.080	129.56	107.14	118.35
$CD_{0.05}$	0.28	NS	NS	NS	NS	NS	5.85	7.04	6.48

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