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Effect of growing media and plant spacing on soil and plant nutrients under protected cultivation in sweet pepper

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Abstract
An experiment was conducted during 2015 and 2016 at vegetable farm Department of Vegetable Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni to study the effect of growing media and plant spacing on soil and plant nutrients under protected cultivation in sweet pepper. The experiment was laid out in randomized block design (Factorial) under polyhouse with 12 treatment combinations. On the basis results summarised as that the M_4 treatment (Soil + Cocopeat + Vermicompost + FYM (2:1:0.5:0.5)) significantly increase the available N, P, K with average value of 351.47, 54.76 and 482.46 kg/ha which was statistically at par with M_3. Similarily, total plant nutrient content was highest under M_4 (3.24% N, 0.36% P and 3.31% K) which was statistically at par with M_3. Plant spacing and interaction did not showed significant effect on available N, P, K content of soil and total N, P, K content in plant.

Keywords: Growing media, available soil nutrient, total plant nutrient

Introduction
Sweet pepper (*Capsicum annuum* L. var. grossum Sendt; 2n = 24) has been known since the beginning of civilization in the Western Hemisphere. It has been a part of the human diet since 7500 BC (MacNeish 1964) [1]. Sweet pepper is also known with a number of other names like pepper, bell pepper, capsicum, paprika etc. Sweet pepper generally refers to non-pungent blocky chillies belonging to the family solanaceae. It is a native of Mexico with secondary centre of origin in Guatemala (Heiser and Smith, 1953) [2], was introduced in India by the Britishers in the 19th century in Shimla hills. It is widely grown in the tropics, sub-tropics and warmer temperate regions of the world. In India, it is grown in an area of 32,150 HA with a production of 182,500 tonnes and productivity of 5.7 tonnes/ha. In Himachal Pradesh, total area under sweet pepper is 2,070 hectares and production is 34,130 tonnes with productivity of 16.5 tonnes/ha (Anonymous, 2015) [3]. One of the most important cultural inputs involved in greenhouse crop production is the type of the growing media used. Different growing media such as soil, vermicompost, cocopeat, FYM and sand etc. or the mixture of these substrates in different ratio had significant effects on production and quality of the crop. These are very important to maintain the fertility and productivity of the agricultural system. Growing media plays an important role in successful cultivation of any crop. It should have a property of good water holding capacity and also able to drain excess water to come to field capacity which creates congenial root environment. For proper plant growth, organic fertilizers such as farmyard manure and vermicompost etc. provide consistently all essential nutrients, be it macro or micro, in an adequate quantity resulting in healthy growth of the plants. The more incorporation of organic matters in the media are expected to improve the physical structure of the soil, enhance the population of micro-organisms and increase the potential availability of growth influencing substances.

Material and Methods
A field experiment was conducted at experimental farm of Department of Vegetable Science, Dr Y. S. Parmar University of Horticulture and Forestry, Nauni during 2015 and 2016. The experiment was laid out in randomized block design with twelve treatments in three replications. The soil of experimental farm was sandy loam in texture having nearly neutral pH (6.57) and normal electrical conductivity (0.45 dS/m). The mean initial available NPK content

of soil was 328.52, 41.35 and 460.50 kg/ha, respectively. The treatments detail are M1S1 (Soil + Sand + FYM (2:1:1) + 45×30), M1S2 (Soil + Sand + FYM (2:1:1) + 45×45), M1S3 (Soil + Sand + FYM (2:1:1) + 45×60), M2S1 (Soil + Cocopeat + FYM (2:1:1)+ 45×30), M2S2 (Soil + Cocopeat + FYM (2:1:1)+ 45×45), M2S3 (Soil + Cocopeat + FYM (2:1:1)+ 45×60), M3S1 (Soil + Cocopeat + Vermicompost (2:1:1) + 45×30), M3S2 (Soil + Cocopeat + Vermicompost (2:1:1) + 45×45), M3S3 (Soil + Cocopeat + Vermicompost (2:1:1) + 45×60), M4S1 (Soil + Cocopeat + Vermicompost + FYM (2:1:0.5:0.5) + 45×30), M4S2 (Soil + Cocopeat + Vermicompost + FYM (2:1:0.5:0.5) + 45×45), M4S3 (Soil + Cocopeat + Vermicompost + FYM (2:1:0.5:0.5) + 45×60) were applied. The seeds of F1 hybrid 'Orobelle' were sown in plastic trays (72 holes) inside the mist chamber of Department of Vegetable Science for raising healthy and disease free seedlings in vermicompost based media. The seedlings were ready for transplanting after 70 to 75 days of sowing.

Collection and preparation of soil sample and analysis

Representative soil samples from 0-15 cm depth were collected from the experimental plot. Collected soil sample were air dried in shade and ground with the help of pestle and mortar. These ground samples were then passed through 2 mm sieve and stored in polyethylene bags for further analysis of soil to determine available N, P and K. The samples were spread on a filter paper for air drying and were subsequently put in paper bags, which were kept in hot air oven at 60 ± 5 °C for 48 hours for drying. The dried samples were crushed, ground and stored in polythene bags for the estimation of N, P and K contents.

Digestion of samples and analysis (growing media)

Well ground samples of known weight of different growing media were digested in diacid mixture prepared by mixing concentrated HNO_3 and $HClO_4$ in the ratio of 4:1 observing all relevant precautions as laid down by Piper (1966) [9] for the nutrients of P and K. Separate digestion was carried out for nitrogen estimation using concentrated H_2SO_4 and digestion mixture (Potassium Sulphate 400 parts, Copper Sulphate 20 parts, Mercuric Oxide 3 parts, Selenium Powder 1 part) as suggested by Jackson (1973) [4].

Available N was estimated by alkaline potassium permanganate method suggested by (Subbiah and Asija, 1956) [5]. Available P was estimated by olsen methods (Olsen *et al.*, 1954) [6]. Avalible K was estimated by Normal neutral ammonium acetate method (Merwin and Peech, 1951) [7]. Leaf samples were collected and prepare as per the method suggested by Chapman (1964) [8] for the estimation of N, P and K.

Digestion of leaf sample

Well ground samples of known weight were digested in diacid mixture prepared by mixing concentrated HNO_3 and $HClO_4$ in the ratio of 4:1 observing all relevant precautions as laid down by Piper (1966) [9] for the nutrients of P and K. Separate digestion was carried out for nitrogen estimation using concentrated H_2SO_4 and digestion mixture (Potassium Sulphate 400 parts, Copper Sulphate 20 parts, Mercuric Oxide 3 parts, Selenium Powder 1 part) as suggested by Jackson (1973) [4].

Table 1: Methods used for estimating N, P and K content of capsicum leaves

Particulars	Method employed	Reference(s)
N	Microkjeldhal distillation	AOAC (1970) [10]
P	Vandotomolybdo-phosphoric yellow colour method	Jackson (1973) [11]
K	Atomic absorption spectrophotometer (AAS)	Jackson (1967) [12]

Result and Discussion

Effect on available N

The results of study indicated that the growing media and plant spacing significantly influenced the available N. Available N content was maximum under treatment M_4 (348.61 and 354.32 kg /ha) comprising of Soil +Coco peat + Vermicompost + FYM (2:1:0.5:0.5), which was statistically at par with M_3 (347.50 and 350.83 kg/ha) comprised of Soil + Coco peat + Vermicompost in ratio of 2:1:1 during 2015 and 2016, respectively. The minimum (335.83 and 338.73 kg/ha) nitrogen content was recorded in M_1 comprising of Soil+Sand+FYM (2:1:1) during both the years of study. The plant spacing also significantly influenced the nitrogen content of growing media. The maximum nitrogen content (344.34 kg/ha) was noted in the plant spacing S_3 comprising of 45 × 60 cm, which was statistically at par with plant spacing S_2 (342.42 kg/ha), whereas, minimum nitrogen (341.72 kg/ha) content was recorded in the plant spacing S_1 (45 × 30 cm) during 2015 while during 2016, plant spacing showed non-significant effect on nitrogen content of growing media. Interaction effect of growing media and plant spacing was found to be non-significant on available nitrogen content.

Increase in available N might be attributed to the direct addition of nitrogen through vermicompost and FYM, which harboured an array of soil microbes, which could convert organically bound N to inorganic form to the available pool of the soil.

Effect on available P

Growing media had a significant effect on available P content of growing media during both the year of study. Maximum (52.97 and 56.55 kg/ha) phosphorus content was recorded in M_4 comprised of Soil +Coco peat + Vermicompost + FYM (2:1:0.5:0.5) which was at par with M_3 (51.20 and 53.99 kg/ha) comprising of Soil +Coco peat + Vermicompost in ratio of 2:1:1, whereas, minimum (46.17 and 48.26 kg/ha) phosphorus content was recorded in M_1 comprised of Soil+Sand+FYM in the ratio of 2:1:1 during both the years of study respectively. Plant spacing had a non significant effect on available phosphorus during 2015 while non significant effect during 2016.

Table 2: Main effect and interaction effect of growing media (M) and plant spacing (S) on available N P K content (kg/ha) of growing media after completion of experiment

Treatments	Available N content after the experiment (kg/ha)			Available P content after the experiment (kg/ha)			Available K content after the experiment (kg/ha)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
M_1	335.83	338.73	337.28	46.17	48.26	47.22	468.30	469.76	469.03
M_2	339.36	341.89	340.62	48.08	51.27	49.68	469.04	471.33	470.18

M_3	347.50	350.83	349.17	51.20	53.99	52.59	478.42	480.46	479.44
M_4	348.61	354.32	351.47	52.97	56.55	54.76	479.75	485.17	482.46
Mean	342.83	346.45	344.63	49.61	52.52	51.06	473.88	476.68	475.28
$CD_{0.05}$	2.27	3.51	2.95	2.77	5.30	2.68	9.21	10.07	9.65
S_1	341.72	345.30	343.51	48.92	50.88	49.90	473.93	475.17	474.55
S_2	342.42	346.13	344.27	49.63	53.32	51.47	475.34	477.62	476.48
S_3	344.34	347.91	346.12	50.28	53.36	51.82	472.36	477.26	474.81
Mean	342.83	346.45	344.63	49.61	52.52	51.06	473.88	476.68	475.28
$CD_{0.05}$	1.97	NS	NS	NS	4.59	NS	NS	NS	NS
Interaction:									
M_1S_1	335.00	338.05	336.53	45.50	46.17	45.83	467.61	469.08	468.35
M_1S_2	335.50	338.07	336.78	46.02	48.95	47.49	468.01	469.95	468.98
M_1S_3	337.00	340.08	338.54	47.00	49.67	48.33	469.28	470.25	469.77
M_2S_1	338.15	340.72	339.43	47.50	49.31	48.41	469.07	470.40	469.73
M_2S_2	339.25	342.02	340.63	48.25	52.00	50.13	470.00	472.78	471.39
M_2S_3	340.67	342.95	341.81	48.50	52.50	50.50	468.04	470.81	469.43
M_3S_1	346.00	350.00	348.00	50.61	52.68	51.65	477.02	478.10	477.56
M_3S_2	346.83	350.33	348.58	51.01	55.00	53.01	480.20	482.65	481.43
M_3S_3	349.67	352.17	350.92	51.97	54.28	53.13	478.03	480.64	479.34
M_4S_1	347.72	352.43	350.08	52.07	55.34	53.70	482.01	483.08	482.55
M_4S_2	348.10	354.08	351.09	53.22	57.31	55.27	483.17	485.10	484.13
M_4S_3	350.02	356.45	353.23	53.63	57.00	55.32	474.07	487.33	480.70
Mean	342.83	346.45	344.63	49.61	52.52	51.06	473.88	476.68	475.28
$CD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS

M1: Soil +Sand+FYM (2:1:1), M2: Soil + Coco peat+ FYM (2:1:1), M3: Soil+Cocopeat+Vermicompost (2:1:1), M4: Soil +Coco peat + Vermicompost + FYM (2:1:0.5:0.5), S1: (45 × 30), S2: (45 × 45), S3: (45 × 60)

The maximum (53.36 kg/ha) available phosphorus content was recorded in the plant spacing S3 (45 cm × 60 cm) whereas, minimum (53.32 kg/ha) available phosphorus content was recorded in plant spacing S1 (45 cm × 30 cm). Interaction had non-significant effect on available phosphorus content of growing media.

The increase in available P content might be due to the incorporation of the organic growing media, which attributed to the direct addition of P as well as release of various organic acids during decomposition might have helped in solubilization of native as well as organic P. The organic materials form a cover on sesquioxides and thus reduce the phosphate fixing capacity of the soil.

Effect on Available K

The result showed that growing media had a significant effect on available K content while effect of plant spacing and their interaction had a non significant effect on available potassium content. Maximum available potassium content (479.75 and 485.17 kg/ha) was recorded in M4 comprised of Soil +Coco peat + Vermicompost + FYM in ratio of 2:1:0.5:0.5, which was at par with M3 (478.42 and 480.46 kg/ha) comprising of Soil +Coco peat + Vermicompost (2:1:1), whereas, minimum available potassium content (468.30 and 469.76 kg/ha) was recorded in M1 comprised of Soil+Sand+FYM in ratio of 2:1:1 during both the years of study, respectively.

The beneficial effect of cocopeat, vermicompost and FYM on available K may be ascribed to the direct potassium addition to the potassium pool of the soil besides the reduction in potassium fixation and its release due to interaction of organic matter with clay particles. The maximum availability of the K was reported by the plant spacing of 45 × 45 cm. The beneficial effects of organic manures in promoting soil productivity has earlier also been reported by Parmar *et al.* (2006) [12].

As stated earlier, the gain in soil nutrient status in terms of available N, P and K were higher in treatments with vermicompost in comparison to enriched compost which may be ascribed to its better nutrient contents (Das *et al*., 2006) [13]. Reddy and Reddy (2011) [14] reported the content as of available N, P and K in soil due to application of different manures in the order: vermicompost > poultry manure > neem cake > farm yard manure. The difference in soil available N, P and K contents in plots treated with different manures might be attributed to the variation in their inherent capacity to supply these nutrients. Prativa and Bhattarai (2011) [15] stated that in organically manured soils the applied manure holds the nutrient and retains losses. Accordingly, they obtained the maximum available N, P and K to be 382.80, 100.40 and 230.80 kg/ha, respectively after harvesting tomato, they explained that the mixing of organic manure (more importantly vermicompost and FYM) might have reduced the nitrogen losses, improved the fertilizer use efficiency thus increasing the availability of N. The increase in P is attributable to the fact that vermicompost in soil might have helped in the solubilisation of fixed P to soluble form making it easily available to the plant, whereas, high availability of K might be due to enhancement in K availability by shifting the equilibrium among the form of K from relatively exchangeable K to soluble K forms in the soil.

Effect of growing media and plant spacing on total plant N, P, K content

Effect on total N content

Effect growing media and plant spacing showed a significant effect on total N content while interaction had a non significant on total N content during both the years of study. Maximum total N (3.27 and 3.21 %) was recorded under M4 which was statistically at par with M3 (3.21 and 3.12 %) while minimum (2.34 and 2.24 %) was under M1 during 2015 and 2016, respectively. In case of plant spacing maximum total nitrogen content (2.98 and 2.87 %) was recorded with the plant spacing S3 comprising of 45 × 60 cm, which was statistically at par with plant spacing S2 (2.92 and 2.79 %) comprising of 45 × 45 cm, whereas, minimum total nitrogen content (2.79 and 2.69 %) was recorded with the plant spacing S1 comprising of 45 × 30 cm during both the years of study.

The organic manures like cocopeat, vermicompost and FYM based growing medium might have enhanced the uptake of applied nitrogen by contributing the growth hormones like auxins and cytokinins besided fixing the atmospheric nitrogen and mobilizing the phosphorus of the soil better than only Sand and FYM based growing medium, which results in higher absorption of nitrogen (Chatterjee, 2009) [16].

Effect on total P content

The result showed that growing media and plant spacing had a significant effect on total P content while the interaction had a non-significant effect. In case of growing media maximum phosphorus content (0.37 and 0.35 %) were recorded in M4 comprising of Soil +Coco peat + Vermicompost + FYM (2:1:0.5:0.5) which were at par with M3 (0.36 and 0.34 %) comprising of Soil +Coco peat + Vermicompost (2:1:1), whereas, minimum phosphorus content (0.32 and 0.30 %) was recorded in M1 comprising of Soil+Sand+FYM (2:1:1) during both the years of study, respectively. In case of plant spacing, maximum phosphorus content (0.36 and 0.34 %) was recorded in plant spacing S3 comprising of 45 cm × 60 cm, which was statistically at par with both the plant spacings S2 (0.35 and 0.33 %) comprising of 45 × 45 cm and minimum was recorded in S1 (0.33 and 0.31 %) comprising of 45 × 30 cm during both the years of study, respectively.

This is due to the fact that the root growth particularly the development of lateral roots and fibrous rootlets which are responsible for nutrients uptake from the soil is positively encouraged by phosphorus (Barker and Pilbeam, 2007) [17]. According to Marschner (1995) [18], the increment in the yield of crop is due to N and P combination might be associated with the synergistic effect of these two nutrients on photosynthetic activity, translocation of assimilates and more absorption of nutrients by the plants.

Effect on total K content

The data pertaining to the effect of growing media and plant spacing on total potassium in the plant had a significant effect while interaction had a non -significant effect. In case of growing media, maximum potassium content (3.35 and 3.27%) were recorded in M4 comprising of Soil +Coco peat + Vermicompost + FYM (2:1:0.5:0.5) which were statistically at par with M3 (3.26 and 3.22 %) comprising of Soil +Coco peat + Vermicompost (2:1:1) whereas, minimum potassium content (3.01 and 2.80 %) was recorded in M1 comprising of Soil+Sand+FYM (2:1:1) during both the years of study, respectively. In case of plant spacing maximum potassium content (3.24 and 3.16 %) was recorded in plant spacing S2 comprising of 45 × 45 cm, which was statistically at par with plant spacing S3 (3.22 and 3.22 %) comprising of 45 × 60 cm, whereas, minimum potassium content (3.14 and 3.02 %) was recorded in plant spacing S1 comprising of 45 × 30 cm during both the years of study, respectively.

Potassium is a mobile element within the soil having higher moisture content and moves with water to different plant tissues. Potassium has a major role in plant metabolism as it activates some enzymes especially involved in the metabolism of carbohydrates. Under high levels, starch moves efficiently from sites of production to storage. In addition, it plays a potential role in the transport of water and essential nutrients throughout the plant in the xylem (Mansour, 2006) [19]. Potassium is also known to regulate opening and closing of stomata which are essential for photosynthesis, water

Table 3: Main and interaction effect of growing media (M) and plant spacing (S) on total N P K content of plant

Treatments	N content of plant (%)			P content of plant (%)			K content of plant (%)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
M_1	2.34	2.24	2.29	0.32	0.30	0.31	3.01	2.80	2.90
M_2	2.77	2.57	2.67	0.34	0.31	0.33	3.18	3.09	3.13
M_3	3.21	3.12	317	0.36	0.34	0.35	3.26	3.22	3.24
M_4	3.27	3.21	3.24	0.37	0.35	0.36	3.35	3.27	3.31
Mean	2.90	2.78	2.84	0.35	0.33	0.34	3.20	3.10	3.15
$CD_{0.05}$	0.11	0.09	0.10	0.02	0.02	0.02	0.09	0.13	0.11
S_1	2.79	2.69	2.74	0.33	0.31	0.32	3.14	3.02	3.08
S_2	2.92	2.79	2.86	0.35	0.33	0.34	3.24	3.16	3.20
S_3	2.98	2.87	2.92	0.36	0.34	0.35	3.22	3.11	3.16
Mean	2.90	2.78	2.84	0.35	0.33	0.34	3.20	3.10	3.15
$CD_{0.05}$	0.10	0.08	0.09	0.02	0.02	0.02	0.08	0.11	0.10
Interaction:									
M_1S_1	2.25	2.16	2.21	0.30	0.28	0.29	2.88	2.62	2.75
M_1S_2	2.32	2.21	2.27	0.32	0.30	0.31	3.12	2.97	3.04
M_1S_3	2.45	2.34	2.40	0.34	0.32	0.33	3.02	2.80	2.91
M_2S_1	2.68	2.40	2.54	0.33	0.30	0.32	3.14	3.02	3.08
M_2S_2	2.77	2.60	2.69	0.34	0.31	0.33	3.19	3.10	3.15
M_2S_3	2.85	2.70	2.77	0.36	0.33	0.34	3.20	3.16	3.18
M_3S_1	3.09	3.08	3.08	0.35	0.32	0.33	3.25	3.17	3.21
M_3S_2	3.33	3.13	3.23	0.37	0.34	0.36	3.27	3.25	3.26
M_3S_3	3.22	3.15	3.19	0.37	0.35	0.36	3.27	3.25	3.26
M_4S_1	3.15	3.13	3.14	0.36	0.34	0.35	3.30	3.27	3.28
M_4S_2	3.25	3.22	3.24	0.37	0.35	0.36	3.37	3.32	3.34
M_4S_3	3.40	3.28	3.34	0.38	0.36	0.37	3.38	3.22	3.30
Mean	2.90	2.78	2.84	0.35	0.33	0.34	3.20	3.10	3.15
$CD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS

M1: Soil +Sand+FYM (2:1:1), M2: Soil + Coco peat+ FYM (2:1:1), M3: Soil+Cocopeat+Vermicompost (2:1:1), M4: Soil +Coco peat + Vermicompost + FYM (2:1:0.5:0.5), S1: (45 × 30), S2: (45 × 45), S3: (45 × 60) and nutrient transport and plant pooling. Soil: Cocopeat: Vermicompost: FYM (2:1:0.5:0.5) with 45 × 60 cm and also with 45 × 45 cm led to the better nutrient supply to the plants. Similar results were recorded by Arancon *et al*. (2003) [20], Malik *et al*. (2011) [21], Narayan *et al*. (2004) [22], Roy *et al*. (2011) [23] and Shehata *et al*. (2004) [24].

Conclusion

It is concluded from the above study that the soil and plant nutrient content was highest under growing media having soil + cocopeat + vermicompost + FYM (M4) in the ratio of 2:1:0.5:0.5 but plant spacing and their interaction didnot show significant effect on soil and plant nutrient conent. The M4S3 is the best treatment combination to maintain nutrient status in soil as well as in plants.

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