Int.J.Curr.Microbiol.App.Sci (2017) *6*(11): 2556-2568

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 11 (2017) pp. 2556-2568**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.611.301

Response in Strawberry (*Fragaria* × *ananassa* Duch. 'Sweet Charlie') Growth to Different Substrates and Containers under Greenhouse

Vikas Kumar Sharma* **and Anil Kumar Godara**

Department of Horticulture, CCS Haryana Agricultural University,
Hisar- 125004, Haryana, India
**Corresponding author*

Keywords

Artificial media, Cocopeat, Growth, Perlite, Substrate combination.

Article Info

Accepted:
20 September 2017
Available Online:
10 November 2017

A B S T R A C T

Strawberry is being promoted for year round production due to its health properties and attractive fruit, and this has been made possible through soilless cultivation. Production of strawberry cultivar 'Sweet Charlie' under soilless system along with control (soil) in three types of containers with two different sizes in a passively ventilated greenhouse was attempted. Different combinations of substrates and containers significantly influenced the vegetative growth in strawberry, whereas, container size had significant effect only on number of leaves, plant spread and crown diameter. The maximum, number of leaves (10.45 and 15.42), petiole length (9.19 cm and 9.18 cm), plant height (15.26 cm and 16.27 cm), plant spread (27.43 cm and 30.24 cm) and crown diameter (17.44 mm and 18.10 mm) were observed in S_2 (cocopeat + perlite + vermicompost, 3:1:1) followed by S_1 (cocopeat + perlite + vermicompost, 2:1:1), whereas, minimum growth was observed in control (soil).In future, these experimental results will prove very useful to find out most suitable substrate combination and container for better vegetative growth in strawberry.

Introduction

Strawberry is generally grown in soil worldwide. It is a sensitive plant and a number of organisms affect almost all parts including roots, crown, leaves and fruits. The various fungi in association with nematodes cause diseases, reduce the yield potential and increase the mortality. To eliminate the soil borne diseases and pest the use of artificial media is gaining popularity and number of soilless substrate/ media can be used to substitute the soil (De-Rijck and Schrevens, 1998). Soilless culture may be an effective alternative to soil-based cultivation (Albaho *et al.,* 2008) and exploitation of local materials for use as growing media with specific physico-chemical properties (Ortega *et al.,* 1996), which exhibit direct and indirect effects on plant growth and production (Verdonck *et al.,* 1981). The commonly used organic substrate in India, being cocopeat have the high water holding and cation exchange capacity, whereas, perlite provides the required porosity to the media. The application of vermicompost in soilless culture increased strawberry growth and yields (Arancon *et al.,* 2004) because it contains available forms of nutrients such as nitrogen, exchangeable phosphorus, potassium, calcium, and magnesium (Edwards and Burrows, 1988) besides micronutrients. The appropriate proportion of the substrate in strawberry not only increases

the yield potential but also improves the quality of the fruits by accurate control over the supply of water, nutrients, root temperature and pH (Olympios, 1993).The size and type of the pot is important for the sufficient root development, which results in a significant influence on growth, canopy, yield and quality indicators in different crops (Manole *et al.*, 2008; Krezel and Kolota, 2009). A number of pots are available in the market of the different size and type for different crops. Strawberry has large number of roots but the more than 90% of the roots are confined to the 20-30 cm depth (Mann, 1930). The use of artificial media may further reduce the depth of roots as the plant can meet the requirement easily due to appropriate air water relation and nutrient holding capacity. Keeping in view the above points, an attempt was made to determine the effect of different substrate combinations and containers vegetative growth of strawberry (*Fragaria* × *ananassa* Duch.) cv. Sweet Charlie.

Materials and Methods

Experimental site and material

The experiment was conducted at Hi-tech greenhouse of Department of Horticulture, CCS Haryana Agricultural University during 2013-14 and 2014-15 growing season. Three substrates cocopeat, perlite and vermicompost were used to create the different treatments in different proportion (by volume) for plant propagation (Table 1). The plants of strawberry cultivar 'Sweet Charlie' were planted under natural light condition during the first week of October after treating with Carbendazim and monocrotophos. Holes were made at the bottom of each container to allow the drainage the excess water. The greenhouse with facility of controlling temperature, humidity and light with automation system for irrigation and fertigation was used. The transplanted plants were kept under uniform condition in poly-house during the study period where all the management practices were carried out as per the package of practices. The pH for this experiment maintained from 6.0 - 6.5 to facilitate the maximum uptake of elements. The Electrical Conductivity (EC) for soilless growing strawberry is maintained below 1.5 mS cm^{-1} for better growth, yield and good quality fruits. The standard and uniform fertilizer solution was used for whole course of investigation. The vegetative formulation used from plant establishment until fruit set on the first truss then a fruiting formulation introduced. The fertigation system was open drip irrigation with no circulation, using 2 liter/ hour capacity inline lateral drippers installed on each pot.

Containers

Polyethylene Bags, PVC Pots and Earthen Pots

Polyethylene Bags (C_1)

CS_1) 16 × 16 cm
CS_2) 20 × 20 cm

PVC Pots (C_2)

CS_1) 15 × 15 cm
CS_2) 25 × 25 cm

Earthen Pots (C_3)

CS_1) 15 × 15 cm
CS_2) 25 × 25 cm

Methodology and observations recorded

The number of leaves per plant was counted from the time of transfer to the end of growing season (October-March) at fortnightly interval and the average number of leaves per plant was calculated at each

observation. Petiole length of three randomly selected leaves per plant was measured with the help of scale and the average of which was expressed as average petiole length in centimeters. The height of the plant was measured individually with a measuring scale from the crown level to the apex of primary leaves and result expressed as average height in centimeters. The plant spread was calculated by measuring the canopy of plant in East- West (E-W) and North- South (N-S) direction with the scale and the average of both was expressed as plant spread in centimeters. The diameter of crown of plant was measured with the help of Vernier Calipers and expressed in millimeters.

Statistical analysis

The data were analyzed according to the procedure for analysis of completely randomized design (CRD) as given by Panse and Sukhtme (1984). The overall significance of difference among the treatments was tested, using critical differences (C.D.) at 5% level of significance. The results were statistically analyzed with the help of a windows based computer package OPSTAT (Sheoran, 2004).

Results and Discussion

The number of leaves per plant differed significantly due to different substrate combinations, containers and their size (Table 2). The two-way interactions between substrates and containers; container and container size were found significant. The three way interactions of substrates combination, container and container size were absent during 2013-14, while present during 2014-15 growing season. The number of leaves per plant increased significantly with the use of all media combinations compared to the soil. The data revealed that the S_2 produced maximum number of leaves (10.45 and 15.42) per plant followed by S_1 (9.88 and 14.84) and the minimum number of leaves (7.86 and 9.59) were observed in soil in both seasons, respectively. The plants grown in PVC pots had maximum number of leaves (9.64 and 14.18) per plant followed by earthen pots (9.13 and 12.83), while minimum were (8.68 and 12.09) recorded in polyethylene bags. The number of leaves increased significantly with the use of large sized container in all three types of pots. The plants grown in CS_2 PVC pots with S_2 media produced maximum number of leaves (18.43) per plant during 2014-15.

Petiole length in strawberry plants was affected significantly due to the combinations of substrates and containers, whereas, non-significant effect on petiole length was observed due to container size (Table 3). During 2013-14, the interactions of substrate and container were found significant and during 2014-15, the two factor interactions between substrate and container and container and container size except all the factors of the variation were found significant. A perusal data given in Table 3 suggested that, the S_2 gave maximum petiole length (9.19 cm and 9.18 cm) and the minimum petiole length (7.09 cm and 7.64 cm) was observed in control (S_7). The petiole length was found maximum in PVC pots (8.26 cm and 8.73 cm) followed by polyethylene bags (8.05 cm and 8.35 cm), whereas, the shortest petiole (7.64 cm and 7.97 cm) was observed in earthen pot. The strawberry plants when grown in PVC pots with S_2 combination gave maximum petiole length (9.60 cm and 9.80 cm) and were found superior to all the treatments in both the growing seasons.

Difference in the height of established plants because of substrate combinations and container were significant (Table 4). The pair wise interactions of substrates and container type were found significant during both years,

while interactions of container and container size were observed only during 2014-15. Other two and three way interactions between the treatments were absent. The substrate combination S_2 resulted maximum plant height (15.26 cm and 16.27 cm) followed by S_1 (14.83 cm and 15.58 cm) and the lowest plant height (12.81 cm and 13.59 cm) was noted in control. Among the container used plants grown in PVC pots had tallest plants (14.57 cm and 15.40 cm) followed by earthen pots (14.17 cm and 14.75 cm) and shortest plant height (13.45 cm and 14.32 cm) was observed in C_1 (polyethylene bags). Thus, strawberry plants grown with S_2 in PVC pots had tallest stature (15.83 cm and 16.88 cm) and were marked superiority among all the treatments during both the years of investigation. During 2014-15, the plants were grown in CS_2 of PVC pots resulted maximum plant height (16.16 cm) than other combinations.

The difference in spread of plants due to combinations of substrate, container and container size were significant (Table 5). The interactions of substrates and containers, container and container size and all these factors were also significant. All substrates significantly increased the plant spread compared to the soil. The substrate combination S_2 gave highest plant spread (27.43 cm and 30.24 cm) followed by S_1 (26.04 cm and 27.88 cm) and the minimum was observed in soil (21.26 cm and 23.06 cm). Among the different containers tried, the PVC pots gave maximum plant spread (25.19 cm and 27.26 cm) followed by earthen pots (24.58 cm and 26.55 cm), whereas, minimum plant spread (22.95 cm and 25.29 cm) was observed in polyethylene bags. The increasing size of the container gradually increased the plant spread in all three types of pots. It It has been concluded that the strawberry plants were grown in S_2 with CS_2 of PVC pots recorded highest plant spread (29.19 cm and 31.64 cm) and were found superior among all the treatments during both growing season, except $S_2C_3CS_2$ (31.37 cm) and $S_2C_1CS_2$ (31.03 cm) during 2014-15.

Different substrates combination, containers and their size produced wide difference in crown diameter (Table 6). The two-way interactions between substrate and container, container and container size and that of all these factors found significant. The crown diameter was significantly increased by all substrate combinations compared to the control.

Table.1 Combination and ratio of different substrates used in experiment

Sr. No.	Substrate code	Substrate used	Ratio
1.	**S_1**	cocopeat + perlite + vermicompost	(2:1:1)
2.	**S_2**	cocopeat + perlite + vermicompost	(3:1:1)
3.	**S_3**	cocopeat + perlite + vermicompost	(4:0:1)
4.	**S_4**	cocopeat + perlite + vermicompost	(4:1:0)
5.	**S_5**	cocopeat + perlite + vermicompost	(4:1:1)
6.	**S_6**	cocopeat + perlite + vermicompost	(4:1:2)
7.	**S_7 (control)**	Soil	-

Table.2 Effect of different substrate combinations, containers and their size on number of leaves per plant in strawberry cv. Sweet Charlie

Substrates/ media	Containers (C)									Overall mean
	2013-2014									
	Polyethylene Bags (C_1)			PVC Pots (C_2)			Earthen Pots (C_3)			
	CS_1	CS_2	Mean	CS_1	CS_2	Mean	CS_1	CS_2	Mean	
S_1	8.85	9.75	**9.30**	9.50	11.42	**10.46**	8.92	10.87	**9.89**	**9.88**
S_2	8.92	10.53	**9.72**	9.93	12.43	**11.18**	9.53	11.38	**10.46**	**10.45**
S_3	7.95	8.62	**8.28**	8.15	10.35	**9.25**	8.03	9.13	**8.58**	**8.70**
S_4	7.72	8.22	**7.97**	7.95	9.03	**8.49**	7.77	8.88	**8.32**	**8.26**
S_5	8.43	9.25	**8.84**	9.07	10.45	**9.76**	8.85	9.52	**9.18**	**9.26**
S_6	8.58	9.50	**9.04**	9.30	11.05	**10.17**	9.15	10.17	**9.66**	**9.62**
S_7 (Control)	7.23	8.00	**7.62**	7.52	8.83	**8.18**	7.45	8.13	**7.79**	**7.86**
Mean	**8.24**	**9.12**	**8.68**	**8.77**	**10.51**	**9.64**	**8.53**	**9.73**	**9.13**	**9.15**
CD (P = 0.05)	**Substrate = 0.20; Container = 0.13; Container size = 0.11; Substrate × Container = 0.35**									
	Container ×Container size = 0.19; Substrate × Container × Container size = N.S.									
2014-2015										
S_1	12.17	15.42	**13.79**	14.75	17.50	**16.12**	13.27	15.93	**14.60**	**14.84**
S_2	13.17	15.67	**14.42**	15.05	18.43	**16.74**	14.18	16.05	**15.12**	**15.42**
S_3	10.10	12.60	**11.35**	11.85	16.05	**13.95**	11.40	13.23	**12.32**	**12.54**
S_4	9.88	10.80	**10.34**	10.60	12.55	**11.57**	10.33	11.28	**10.81**	**10.91**
S_5	10.45	14.57	**12.51**	13.07	16.28	**14.67**	11.17	14.78	**12.98**	**13.39**
S_6	11.72	14.85	**13.28**	14.63	17.45	**16.04**	12.83	15.70	**14.27**	**14.53**
S_7 (Control)	8.40	9.45	**8.93**	9.26	11.05	**10.15**	9.05	10.36	**9.70**	**9.59**
Mean	**10.84**	**13.34**	**12.09**	**12.74**	**15.62**	**14.18**	**11.75**	**13.91**	**12.83**	**13.03**
CD (P = 0.05)	**Substrate = 0.21; Container = 0.14; Container size = 0.11; Substrate × Container = 0.37**									
	Container ×Container size = 0.20; Substrate ×Container × Container size = 0.53									

S - Substrate; C - Container; CS - Container size; N.S. - Non-significant

Table.3 Effect of different substrate combinations, containers and their size on petiole length (cm) in strawberry cv. Sweet Charlie

Substrates/ media	Containers (C)									Overall mean
	2013-2014									
	Polyethylene Bags (C_1)			PVC Pots (C_2)			Earthen Pots (C_3)			
	CS_1	CS_2	Mean	CS_1	CS_2	Mean	CS_1	CS_2	Mean	
S_1	8.01	8.91	**8.46**	8.30	9.24	**8.77**	7.58	8.69	**8.14**	**8.46**
S_2	8.76	9.39	**9.08**	9.34	9.85	**9.60**	8.72	9.04	**8.88**	**9.19**
S_3	7.50	8.04	**7.77**	7.54	8.26	**7.90**	6.76	7.75	**7.25**	**7.64**
S_4	7.11	7.93	**7.52**	7.26	8.15	**7.71**	6.57	7.48	**7.02**	**7.42**
S_5	7.67	8.55	**8.11**	7.77	8.73	**8.25**	7.29	7.88	**7.58**	**7.98**
S_6	7.79	8.76	**8.28**	7.88	8.78	**8.33**	7.49	7.95	**7.72**	**8.11**
S_7 (Control)	6.93	7.34	**7.13**	7.11	7.39	**7.25**	6.54	7.22	**6.88**	**7.09**
Mean	**7.68**	**8.42**	**8.05**	**7.89**	**8.63**	**8.26**	**7.28**	**8.00**	**7.64**	**7.98**
CD (P = 0.05)	**Substrate = 0.19; Container = 0.12; Container size = N.S.; Substrate × Container = 0.33**									
	Container ×Container size = N.S.; Substrate ×Container × Container size = N.S.									
2014-2015										
S_1	8.50	9.09	**8.80**	8.60	9.94	**9.27**	8.48	8.83	**8.65**	**8.91**
S_2	8.71	9.21	**8.96**	9.03	10.56	**9.80**	8.54	9.04	**8.79**	**9.18**
S_3	7.87	8.66	**8.27**	7.95	8.83	**8.39**	7.43	8.09	**7.76**	**8.14**
S_4	7.46	8.35	**7.91**	7.77	8.67	**8.22**	7.11	7.94	**7.52**	**7.88**
S_5	7.94	8.73	**8.34**	8.10	9.00	**8.55**	7.49	8.33	**7.91**	**8.27**
S_6	8.04	9.00	**8.52**	8.30	9.43	**8.86**	7.58	8.34	**7.96**	**8.45**
S_7 (Control)	7.24	8.15	**7.70**	7.46	8.63	**8.05**	6.88	7.49	**7.19**	**7.64**
Mean	**7.97**	**8.74**	**8.35**	**8.17**	**9.29**	**8.73**	**7.65**	**8.29**	**7.97**	**8.35**
CD (P = 0.05)	**Substrate = 0.17; Container = 0.11; Container size = N.S.; Substrate × Container = 0.30**									
	Container ×Container size = 0.16; Substrate ×Container × Container size = N.S.									

S - Substrate; C - Container; CS - Container size; N.S. - Non-significant

Table.4 Effect of different substrate combinations, containers and their size on plant height (cm) in strawberry cv. Sweet Charlie

Substrates/ media	Containers (C)									Overall mean
	2013-2014									
	Polyethylene Bags (C_1)			PVC Pots (C_2)			Earthen Pots (C_3)			
	CS_1	CS_2	Mean	CS_1	CS_2	Mean	CS_1	CS_2	Mean	
S_1	13.18	15.17	**14.18**	14.78	15.85	**15.32**	14.49	15.50	**14.99**	**14.83**
S_2	14.22	15.40	**14.81**	15.07	16.60	**15.83**	14.76	15.54	**15.15**	**15.26**
S_3	12.28	13.87	**13.07**	13.50	15.09	**14.29**	13.31	14.77	**14.04**	**13.80**
S_4	12.22	13.17	**12.70**	13.13	14.81	**13.97**	12.88	13.57	**13.23**	**13.30**
S_5	12.75	14.02	**13.38**	13.64	15.48	**14.56**	13.44	15.10	**14.27**	**14.07**
S_6	13.01	14.27	**13.64**	14.09	15.76	**14.93**	13.98	15.13	**14.56**	**14.38**
S_7 (Control)	11.68	13.10	**12.39**	12.83	13.31	**13.07**	12.62	13.30	**12.96**	**12.81**
Mean	**12.76**	**14.14**	**13.45**	**13.86**	**15.27**	**14.57**	**13.64**	**14.70**	**14.17**	**14.06**
CD (P = 0.05)	**Substrate = 0.25; Container = 0.16; Container size = N.S.; Substrate × Container = 0.43**									
	Container ×Container size = N.S.; Substrate ×Container × Container size = N.S.									
2014-2015										
S_1	14.94	15.37	**15.16**	15.23	17.12	**16.17**	14.96	15.87	**15.41**	**15.58**
S_2	15.29	16.25	**15.77**	15.97	17.79	**16.88**	15.66	16.63	**16.15**	**16.27**
S_3	12.95	14.33	**13.64**	14.20	15.48	**14.84**	13.98	14.57	**14.28**	**14.25**
S_4	12.78	13.87	**13.32**	13.82	15.36	**14.59**	13.68	14.27	**13.97**	**13.96**
S_5	14.15	15.10	**14.63**	14.59	15.69	**15.14**	14.24	15.17	**14.71**	**14.83**
S_6	14.41	15.28	**14.84**	15.19	16.40	**15.80**	14.83	15.65	**15.24**	**15.29**
S_7 (Control)	12.37	13.43	**12.90**	13.42	15.29	**14.35**	13.29	13.75	**13.52**	**13.59**
Mean	**13.84**	**14.80**	**14.32**	**14.63**	**16.16**	**15.40**	**14.38**	**15.13**	**14.75**	**14.82**
CD (P = 0.05)	**Substrate = 0.20; Container = 0.13; Container size = N.S.; Substrate × Container = 0.34**									
	Container ×Container size = 0.18; Substrate × Container × Container size = N.S.									

S - Substrate; C - Container; CS - Container size; N.S. - Non-significant

Table.5 Effect of different substrate combinations, containers and their size on plant spread (cm) in strawberry cv. Sweet Charlie

Substrates/ media	Containers (C)									Overall mean
	2013-2014									
	Polyethylene Bags (C_1)			PVC Pots (C_2)			Earthen Pots (C_3)			
	CS_1	CS_2	Mean	CS_1	CS_2	Mean	CS_1	CS_2	Mean	
S_1	22.46	26.55	**24.51**	26.37	28.84	**27.60**	23.99	28.05	**26.02**	**26.04**
S_2	25.90	27.16	**26.53**	27.03	29.19	**28.11**	26.86	28.42	**27.64**	**27.43**
S_3	21.29	23.63	**22.46**	23.52	25.24	**24.38**	23.19	25.03	**24.11**	**23.65**
S_4	19.33	22.40	**20.86**	22.04	24.47	**23.26**	21.48	23.98	**22.73**	**22.28**
S_5	21.40	23.94	**22.67**	23.73	26.04	**24.89**	23.43	25.88	**24.66**	**24.07**
S_6	22.32	24.66	**23.49**	24.27	27.80	**26.03**	23.87	26.80	**25.33**	**24.95**
S_7 (Control)	18.41	21.81	**20.11**	21.40	22.76	**22.08**	21.19	21.98	**21.59**	**21.26**
Mean	**21.59**	**24.31**	**22.95**	**24.05**	**26.33**	**25.19**	**23.43**	**25.74**	**24.58**	**24.24**
CD (P = 0.05)	**Substrate = 0.28; Container = 0.18; Container size = 0.15; Substrate × Container = 0.48**									
	Container × Container size = 0.26; Substrate × Container × Container size = 0.68									
2014-2015										
S_1	26.04	27.73	**26.88**	27.63	30.77	**29.20**	26.43	28.67	**27.55**	**27.88**
S_2	28.31	31.03	**29.67**	29.87	31.64	**30.76**	29.22	31.37	**30.30**	**30.24**
S_3	21.51	25.51	**23.51**	25.23	28.36	**26.80**	25.07	27.04	**26.06**	**25.45**
S_4	20.86	25.19	**23.03**	24.57	26.30	**25.43**	24.39	25.78	**25.08**	**24.51**
S_5	25.04	26.24	**25.64**	25.69	28.61	**27.15**	25.61	27.53	**26.57**	**26.45**
S_6	25.49	27.03	**26.26**	26.26	28.86	**27.56**	26.08	28.04	**27.06**	**26.96**
S_7 (Control)	20.38	23.66	**22.02**	23.39	24.43	**23.91**	22.37	24.13	**23.25**	**23.06**
Mean	**23.95**	**26.63**	**25.29**	**26.09**	**28.42**	**27.26**	**25.59**	**27.51**	**26.55**	**26.37**
CD (P = 0.05)	**Substrate = 0.25; Container = 0.16; Container size = 0.13; Substrate × Container = 0.43**									
	Container × Container size = 0.23; Substrate × Container × Container size = 0.61									

S - Substrate; C- Container; CS - Container size

Table.6 Effect of different substrate combinations, containers and their size on crown diameter (mm) in strawberry cv. Sweet Charlie

Substrates/ media	Containers (C)									Overall mean
	2013-2014									
	Polyethylene Bags (C_1)			PVC Pots (C_2)			Earthen Pots (C_3)			
	CS_1	CS_2	Mean	CS_1	CS_2	Mean	CS_1	CS_2	Mean	
S_1	15.57	16.78	**16.18**	17.04	17.71	**17.38**	16.22	17.16	**16.69**	**16.75**
S_2	16.58	17.32	**16.95**	17.26	18.63	**17.94**	16.88	17.96	**17.42**	**17.44**
S_3	12.82	14.87	**13.85**	14.69	15.46	**15.07**	13.98	15.20	**14.59**	**14.50**
S_4	11.76	14.51	**13.14**	13.50	14.93	**14.21**	12.88	14.82	**13.85**	**13.73**
S_5	13.97	15.94	**14.95**	15.20	16.29	**15.75**	14.34	15.98	**15.16**	**15.29**
S_6	14.86	16.46	**15.66**	15.71	17.57	**16.64**	15.33	16.95	**16.14**	**16.15**
S_7 (Control)	10.40	11.29	**10.85**	11.25	12.82	**12.03**	11.18	12.70	**11.94**	**11.61**
Mean	**13.71**	**15.31**	**14.51**	**14.95**	**16.20**	**15.58**	**14.40**	**15.82**	**15.11**	**15.07**
CD (P = 0.05)	**Substrate = 0.17, Container = 0.11, Container size = 0.09, Substrate × Container = 0.29**									
	Container × Container size = 0.15, Substrate × Container × Container size = 0.41									
2014-2015										
S_1	15.41	17.93	**16.67**	17.51	18.62	**18.06**	16.95	18.06	**17.50**	**17.41**
S_2	16.87	18.14	**17.51**	18.08	19.32	**18.70**	17.80	18.41	**18.10**	**18.10**
S_3	12.23	15.29	**13.76**	14.81	17.04	**15.93**	14.04	15.95	**15.00**	**14.89**
S_4	12.06	14.59	**13.33**	14.33	15.29	**14.81**	13.82	15.09	**14.46**	**14.20**
S_5	14.75	16.30	**15.52**	15.53	17.28	**16.41**	15.08	16.54	**15.81**	**15.91**
S_6	15.09	17.17	**16.13**	16.70	18.02	**17.36**	15.52	17.81	**16.66**	**16.72**
S_7 (Control)	10.87	12.36	**11.62**	12.01	13.55	**12.78**	11.82	13.41	**12.61**	**12.34**
Mean	**13.90**	**15.97**	**14.93**	**15.57**	**17.02**	**16.29**	**15.00**	**16.47**	**15.74**	**15.65**
CD (P = 0.05)	**Substrate = 0.20, Container = 0.13, Container size = 0.11, Substrate × Container = 0.35**									
	Container × Container size = 0.19, Substrate × Container × Container size = 0.50									

S - Substrate; C - Container; CS - Container size

Among various substrates tried, S_2 resulted in maximum crown diameter (17.44 mm and 18.10 mm) followed by S_1 (16.75 mm and 17.41 mm) and S_6 (16.15 mm and 16.72 mm), while smallest crown diameter (11.61 mm and 12.34 mm) was observed in S_7 (soil) during 2013-14 and 2014-15, respectively. The PVC pots gave largest crown diameter (15.58 mm and 16.29 mm) followed by earthen pots (15.11 mm and 15.74 mm) and the lowest crown diameter (14.51 mm and 14.93 mm) was observed from polyethylene bags. The increasing trend was observed in crown diameter as the increase in the pot size of containers. It has been concluded that strawberry plants were grown in CS_2 of PVC pots in combination with S_2, resulted in maximum crown diameter (18.63 mm and 19.32 mm) and were found superior among all the treatment combinations.

The present studies indicated that the all vegetative growth parameters were significantly influenced by various growing media treatments. All combinations of soilless substrates significantly increased the strawberry growth as compared to control (soil).The variation in the vegetative growth might be due to the properties of different materials used as growing substrates exhibit direct and indirect effects on plant growth. The present results are in line with earlier findings of Verdonck *et al.,* (1981). Schie, (1999) reported that the cocopeat is an organic material with medium ion absorption capacity. It also has aerial porosity and better capacity of water and nutrient maintenance (Por-Hossein *et al.,* 2009). Perlite is considered as a substrate with excellent features in soilless cultivation since it has high water absorption, increases watering efficiency (Inden and Torres, 2004). Vermicompost consists of available forms of nutrition for plant uptake such as nitrates, exchangeable phosphorus, potassium, calcium and magnesium and increased the water retention capacity (Fernandes and Eduardo-Cora, 2004); known as a medium that is one of the effective factors in plant growth and yield (Cantliffe, 2007). The use of different organic and inorganic substrates in appropriate proportion optimize water and oxygen holding and allows the plants better nutrient uptake for sufficient growth and development (Ayesha *et al.,* 2011; Hesami *et al.,* 2012). One of the physiological reasons of growth decrease in conventional system (soil) may be due to a disorder in the plant photosynthetic system (Soltani, 2004). Nourizadeh (2003) reported cocopeat and perlite substrates to be effective in root due to better interchange of the elements especially cations inside the substrate and proper moisture distribution that improves root system and finally plant height. Tabatabaei *et al.,* (2006) concluded that treatments which were mixture of perlite increased plant height. Rumple *et al.,* (1996) found that plant growth of tomato as indicated by plant height, stem diameter, number of leaves was higher in soilless culture than in the soil cultivation. Hassan *et al.,* (2011) observed using coconut husk gave the highest number of leaves and plant height and control (soil cultivation) gave the lowest. The number of leaves decreased as the soil amount increased in the media (Selda and Anapali, 2010). Similarly Ericisli *et al.,* (2005) also reported soilless substrates were effective on growth of strawberry cultivars in terms of above and underground parts of plants. But the contrasting results were reported by Selda and Anapali, 2010, according to them perlite contain 6.9% aluminum which at low pH may be released into the solution and adversely affect the growth of strawberry plants.

Among the containers, the plants grown in PVC pots significantly increased the number of leaves, petiole length, plant height, plant spread and crown diameter. It may be due to that no evaporative cooling takes place in case

of PVC pots and resulting in higher temperature of the rooting media. The higher temperature of rooting media resulted better root and shoot growth of the plant in winter month. Manole *et al.,* (2008) had also reported the significant influence of pot type on the substrate biological activity and growth parameters of plants. These results are in agreement with Cantliffe *et al.,* (2001) and Dafault and Waters (1985), who have also reported the influence of type of growing containers on strawberry plant growth. According to Miralles *et al.,* (2012), white exterior PVC pots reduced the average and maximum temperatures by 3 and 6°C, which improve the plant growth. In present study less growth of strawberry plants was recorded from polyethylene bags. The results are in line with the findings of Paroussi *et al.,* (1995), who reported the strawberry plants grown in white plastic containers produced greatest number of leaves and fresh and dry plant weight under soilless culture in perlite media than black poly bags. However, no-significant difference in number of leaves and plant height was observed between black poly bags and white PVC containers by Hassan *et al.,* (2011).

The number of leaves, plant spread and crown diameter significantly increased with the increase of container size, however, petiole length and plant height did not differ due to container size. Such increase in the number of leaves, plant spread and crown diameter might be due to the volume of media resulting in availability of more water and nutrients besides aeration hence plant growth. The present findings are in accordance with the results of Dafault and Waters (1985) and Durner *et al.,* (2002). Similar results were observed by Sirin and Sevgican (1999), they found the wider bags provide more chance for increasing the active roots in the upper parts of the black bags leading to better growth in cucumber. Present findings are also in close agreement with the earlier findings of NeSmith and Duval (1998) and Cantliffe *et al.,* (2001) in strawberry under soilless culture. However, contrary the pot size used by Phala *et al.,* (2012), the smallest pot may be sufficient for the maximum root growth attainable by the genotype. The large cell size increases the amount of substrate, reduces the number of transplants per tray which increases the costs of package and shipping but the physiological quality of the plants was not affected (Hochmuth *et al.,* 2006).

All combinations of substrates significantly improved the plant growth in strawberry compared to the soil and the substrate combination S_2 (cocopeat + perlite + vermicompost, 3:1:1) was found superior among all the treatments. Maximum growth was observed from the plants grown in PVC pots. Container size also had significant effect on strawberry growth; plants grown in larger container produced better growth than the smaller containers.

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How to cite this article:

Vikas Kumar Sharma and Anil Kumar Godara. 2017. Response in Strawberry (*Fragaria* × *ananassa* Duch. 'Sweet Charlie') Growth to Different Substrates and Containers under Greenhouse. *Int.J.Curr.Microbiol.App.Sci.* 6(11): 2556-2568.
doi: https://doi.org/10.20546/ijcmas.2017.611.301