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EFFECTS OF SUBSTRATES AND CONTAINERS ON ROOT SYSTEM OF HYDROPONICALLY GROWN STRAWBERRY (*FRAGARIA* × *ANANASSA* DUCH.) UNDER GREENHOUSE

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Abstract

The root system of strawberry (*Fragaria*×*Ananassa*Duch.) plants grown hydroponically in different proportion of cocopeat + perlite + vermicompost *viz.*, S_1 (3:1:1), S_2 (4:0:1), S_3 (4:1:0), S_4 (4:1:1) and S_5 (4:1:2) was studied in comparison to soil cultivation (S_0)insmall and large size containers of polyethylene bags (C_1), PVC pots (C_2) and earthen pots (C_3). The maximum length of most developed root (41.10 cm), fresh (16.80 g) and dry (5.42 g) root weight, number of primary roots (90.67) and total root length (4932.06 cm) were obtained from interaction of $S_1C_3$with large size container, whileminimum growth of root system was observed from the interaction of $S_0C_1$with small size container. The effect on root system was found most positive in the plants grown in earthen pots followed by PVC pots and polyethylene bags. The present findings highlights the putative use of substrate S_1(3:1:1) and earthen pots (C_3), which are best for root systemof strawberry.

Introduction

The modern cultivated strawberry (*Fragaria* ×*Ananassa* Duch.) is one of the most delicious, refreshing and soft fruit of the world. Worldwide it is widely distributed as fruit crop due to its genotypic diversity, highly heterozygous nature and broad range of environmental adaptations (Larson 1994).In India, the cultivated area under strawberry is nearly 15600 hectare and commercially grown in Himachal Pradesh, Maharashtra, Uttrakhand, Punjab, Haryana, Western Uttar Pradesh and Madhya Pradesh(Anon.2011).

`In recent past, the strawberry cultivation has been becoming popular in India due to very high returns per unit area in a short span. But the main problem with its cultivation is the loss of plants due to soil borne pathogens, nematodes and the occurrence of soil limited factors. Conventional soil-based cultivation systems are also not water efficient mainly due to loss of excessive irrigation, leaching and evaporation. Thus increased demand for a suitable technology adapted to soilless culture (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). Cocopeat is an organicsubstrate, which has aerial porosity and a good capacity of maintaining water and nutrient whereas,perlite has rich inorganic materials such as iron, sodium and calcium (Djedidi*et al*. 1999). Vermicompost applications in soilless culture increased strawberry growth and yields significantly (Aranconе*t al.* 2004) because it contains available forms of nutrients for plant uptake such as nitrates, exchangeable phosphorus, potassium, calcium and magnesium (Edwards and Burrows 1988). Substrate has a direct effect on the development and performance of root system (Abad *et al*. 2002). The most primary roots in each plant, the length of the longest root string, root and shoot dry weight was obtained from perlite, Fine peat + perlite and peatsubstrates(Ercisli*et al.* 2005) and fresh root weight (Selda and Anapali 2010). The objective of the present study was to compare the performance of root system of strawberry (*Fragaria*× *Ananassa*Duch.) in different mixtures cocopeat, perlite and vermicompost and types and size of containers.

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Materials and Methods

Strawberry (*Fragaria×Ananassa*Duch. cv. Sweet Charlie) plants were grown under natural light condition during October at Hi-tech greenhouse, CCS Haryana Agricultural University, Hisar, located at latitude 29.09°N, longitude 75.43°E and 215-218 meter from mean sea level in western Haryana, India. Three substratesCocopeat, perlite and vermicompost were used to create five treatments in addition to control which were:S_0: Soil cultivation (control), S_1: Cocopeat + perlite + vermicompost (3:1:1), S_2: Cocopeat + perlite + vermicompost (4:0:1), S_3: cocopeat + perlite + vermicompost (4:1:0), S_4: Cocopeat + perlite + vermicompost (4:1:1), S_5: Cocopeat + perlite + vermicompost (4:1:2) and three types of containers C_1 (polyethylene bags, 16 × 16 cm and 20× 20 cm), C_2 (PVC pots, 15 cm and 25 cm) and C_3 (earthen pots, 15 cm and 25 cm).The runners were planted during the second week of October directly in the substrates after treating with carbendazimand monocrotophos.Holes were made on the bottom of each container to allow the drainage of excess water. The six-substrate mixtures with five replications /treatments (with 5 plants/replications) were arranged in single rows on a greenhouse trough.

At the end of the growing season, each plant was evaluated in terms of the length of the most developed roots, fresh and dry root weight, number of primary roots and total length. Root samples from each plant were collected and cleaned and total root length was then measured using a SCAN image analysis system.Data were tested for normality, and then subjected to ANOVA suggested by Gomez and Gomez (1984). Significant differences between mean values were determined using the completely randomized design and following three-way ANOVA. Statistical analyses were performed using OPSTAT (Statistics Analytical Software) developed by department of computer section, CCS, HAU Hisar.

Results and Discussion

The length of most developed root significantly influenced by different substratecombinations, containers and their size (Table 1).The pair-wise and three way interactions among these factors were found significant.Among the different substrate tried,substrateS_1(3:1:1) produced maximum length (30.73 cm) of most developed root followed by S_5(28.42 cm) and the minimum(13.77 cm) was produced in control (soil). The large sized containers produced maximum length of most developed root in all three types of containers. Among different containers used, the earthen pot produced maximum length (28.20 cm) of single root followed by PVC pot (22.22 cm) and the minimum(19.53 cm) was produced by polyethylene bags. The S_1 substrate used in large sized earthen pot produced maximum (41.10 cm) length of most developed root and was found best among all the treatments and minimum length of a single root (12.57 cm) was observed from plants grown in small sized polyethylene bag with soil.This might be due to the better water retention by the soilless substrate, air filled porosity, gas diffusion and better nutrient availability to the roots. Similar results were observed by Ercisli *et al*. (2005), who reported that the highest length of the most developed root was obtained from fine peat + perlite, whereas the lowest length of the most developed root was obtained from forest soil. Contrasting results were reported by Selda and Anapali (2010), observed that perlite mixed with 50% soil provides maximum root length as compared to alone.

Root fresh and dry weight per plant differed significantly on account of substrate, containers and the size of containers (Tables 2 and 3). The interaction between substrate and containers, media and container size, containers and their size and that of three factors interaction of the variation were found significant. The data mentioned here revealed that the earthen pot produced maximum fresh (9.69 g) and dry (2.97 g) root weight followed by PVC pot (7.40 and 2.22 g) and the minimum fresh (5.26 g) and dry (1.93 g) root weight was observed in polyethylene bag. The large container size gave maximum fresh and dry rootweight per plant in all three types of container. The S_1 substr ate gave maximum fresh and

Table 1. Effect of substrates and containers on length of most developed root (cm) of strawberry cv. Sweet Charlie.

Types and size of containers	Substrates						Mean
	S_0	S_1	S_2	S_3	S_4	S_5	
Polyethylene bags							
Small sized	12.57	24.37	19.60	13.03	20.40	22.40	18.73
Large sized	13.40	28.10	20.10	14.37	21.30	24.67	20.32
Mean	**12.99**	**26.24**	**19.85**	**13.70**	**20.85**	**23.54**	19.53
PVC pots							
Small sized	13.90	28.23	20.10	17.20	21.57	24.90	20.98
Large sized	14.27	29.97	22.60	19.30	25.70	28.90	23.46
Mean	**14.09**	**29.10**	**21.35**	**18.25**	**23.64**	**26.90**	22.22
Earthen pots							
Small sized	14.77	32.60	23.90	20.93	26.63	29.43	24.71
Large sized	13.72	41.10	32.60	27.47	35.10	40.20	31.70
Mean	**14.25**	**36.85**	**28.25**	**24.20**	**30.87**	**34.82**	28.20
Mean for media and containers							
C_1	12.98	26.23	19.85	13.70	20.85	23.53	19.53
C_2	14.08	29.10	21.35	18.25	23.63	26.90	22.22
C_3	14.25	36.85	28.25	24.20	30.87	34.82	28.21
General mean	**13.77**	**30.73**	**23.15**	**18.72**	**25.12**	**28.42**	23.32
CD forfactor A*= 0.60		factor B*= 0.43			factor C* = 0.35		
A × B = 1.04	A × C = 0.85		B × C = 0.60		A × B × C = 1.48		

*Factor A = Substrate, Factor B = Containers, Factor C = Size.

Table 2. Effect of substrates and containers on root fresh weight (g) of strawberry cv. Sweet Charlie.

Types and size of containers	Substrates						Mean
	S_0	S_1	S_2	S_3	S_4	S_5	
Polyethylene bags							
Small sized	3.00	5.80	3.50	3.60	5.40	5.63	4.49
Large sized	3.50	8.40	5.60	3.80	6.80	8.03	6.03
Mean	**3.25**	**7.10**	**4.55**	**3.70**	**6.10**	**6.83**	5.26
PVC pots							
Small sized	3.70	8.60	5.73	4.87	7.20	8.17	6.38
Large sized	4.10	11.80	7.60	5.90	10.27	10.80	8.41
Mean	**3.90**	**10.20**	**6.67**	**5.39**	**8.74**	**9.49**	7.40
Earthen pots							
Small sized	3.70	11.00	6.40	5.90	9.20	9.60	7.63
Large sized	4.03	16.80	11.00	9.20	14.30	15.10	11.74
Mean	**3.87**	**13.90**	**8.70**	**7.55**	**11.75**	**12.35**	9.69
Mean for media and containers							
C_1	3.25	7.10	4.55	3.70	6.10	6.83	5.26
C_2	3.90	10.20	6.67	5.38	8.73	9.48	7.39
C_3	3.87	13.90	8.70	7.55	11.75	12.35	9.69
Mean	**3.67**	**10.40**	**6.64**	**5.54**	**8.86**	**9.56**	7.45
CD for factor A*= 0.44		factor B*= 0.31			factor C* = 0.25		
A × B = 0.76	A × C = 0.62		B × C = 0.44		A × B × C = 1.07		

*Factor A = Substrate, Factor B = Containers, Factor C = Size.

Table 3. Effect of substrates and containers on root dry weight (g) of strawberry cv. Sweet Charlie.

Types and size of containers	Substrates						Mean
	S_0	S_1	S_2	S_3	S_4	S_5	
Polyethylene bags							
Small sized	1.11	2.46	1.56	1.14	1.89	2.09	1.71
Large sized	1.26	3.19	1.89	1.72	2.37	2.47	2.15
Mean	**1.19**	**2.83**	**1.73**	**1.43**	**2.13**	**2.28**	1.93
PVC pots							
Small sized	1.28	2.97	1.81	1.61	2.30	2.38	2.06
Large sized	1.30	3.46	2.24	1.73	2.74	2.86	2.39
Mean	**1.29**	**3.22**	**2.03**	**1.67**	**2.52**	**2.62**	2.22
Earthen pots							
Small sized	1.32	3.49	1.89	1.69	2.45	2.63	2.25
Large sized	1.58	5.42	3.14	2.62	4.32	5.04	3.69
Mean	**1.45**	**4.46**	**2.52**	**2.15**	**3.39**	**3.84**	2.97
Mean for media and containers							
C_1	1.19	2.83	1.73	1.43	2.13	2.28	1.93
C_2	1.29	3.22	2.03	1.67	2.52	2.62	2.22
C_3	1.45	4.46	2.52	2.15	3.39	3.84	2.97
Mean	**1.31**	**3.50**	**2.09**	**1.75**	**2.68**	**2.91**	2.37
CD for factor A*= 0.09			Factor B*= 0.06			Factor C* = 0.05	
A × B = 0.15		A × C = 0.12		B × C = 0.09		A × B × C = 0.21	

*Factor A = Substrate, Factor B = Containers, Factor C = Size.

dry root weight (10.40 and 3.50 g) per plant followed by S_5 (9.56 and 2.91 g) and S_4 (8.86 and 2.68 g) substrate and the minimum root weight was observed in control (3.67 and 1.31 g). From data presented in Tables 2 and 3, it could be inferred that the strawberry plant grown in large sized earthen pot with S_1 substrate gave maximum root fresh and dry weight (16.80 and 5.42 g) per plant and was found best among all the treatments, while least fresh and dry root weight (3.00 and 1.11 g) was observed in plants grown with soil in small poly bags. This is may be due to the substrate cause better exchange of elements especially cations inside the substrate and they distribute humidity properly around the root zone and it is finally effective in root system. This investigation was supported by Ebrahimi *et al*. (2012), Roosta and Afsharipoor (2012), Ercisli *et al.* (2005) and Caso *et al*. (2009), who also reported maximum fresh and dry weight of the strawberry resulted from cocopeat + perlite treatment as compared to soil cultivation.

There were significant differences in number of primary roots per plant due to substrate composition, types of container and size (Table 4).The dataalso showed significant interactions between all two and three way interaction. It was resulted from Table 4 that earthen pots produced maximum number (62.08) of primary roots per plant but polyethylene bag produced minimum number (42.30) of primary roots. Among the different substrates used, the S_1 substrate showed maximum number (90.67) of primary roots per plant when grown in large sized earthen pots, while minimum (26.67) primary roots were noticed in control placed in small polyethylene bags. This is may be due to the substrates (cocopeat and perlite) have a proper aerial porosity and better capacity of water and nutrient management. The present findings are in conformity with the findings of Ercisli*et al.* (2005). They observedthat the number of primary roots per plant was affected by the growing media and perlite gave the best results in terms of number of primary roots per plant.

Table 4. Effect of substrates and containers on number of primary roots of strawberry cv. Sweet Charlie.

Types and size of containers	Substrates						Mean
	S_0	S_1	S_2	S_3	S_4	S_5	
Polyethylene bags							
Small sized	26.67	49.33	33.33	32.33	44.33	47.67	38.94
Large sized	29.67	61.00	40.00	36.33	50.66	56.33	45.67
Mean	**28.17**	**55.17**	**36.67**	**34.33**	**47.50**	**52.00**	42.30
PVC pots							
Small sized	32.33	70.33	49.33	42.33	55.33	64.33	52.33
Large sized	37.33	74.33	53.67	45.00	60.00	69.33	56.61
Mean	**34.83**	**72.33**	**51.50**	**43.67**	**57.67**	**66.83**	54.47
Earthen pots							
Small sized	39.33	75.33	55.67	46.00	63.33	66.67	57.72
Large sized	40.33	90.67	56.33	48.00	79.33	84.00	66.44
Mean	**39.83**	**83.00**	**56.00**	**47.00**	**71.33**	**75.34**	62.08
Mean for media and containers							
C_1	28.17	55.17	36.67	34.33	47.50	52.00	42.31
C_2	34.83	72.33	51.50	43.67	57.67	66.83	54.47
C_3	39.83	83.00	56.00	47.00	71.33	75.33	62.08
General mean	**34.28**	**70.17**	**48.06**	**41.67**	**58.83**	**64.72**	52.95
CD for factor A*= 1.97		Factor B*= 1.39			Factor C* = 1.13		
A × B = 3.40	A × C = 2.78		B × C = 1.97		A × B × C = 4.81		

*Factor A = Substrate, Factor B = Containers, Factor C = Size.

Table 5. Effect of substrates and containers on total root length (cm) of strawberry cv. Sweet Charlie.

Types and size of containers	Substrates						Mean
	S_0	S_1	S_2	S_3	S_4	S_5	
Polyethylene bags							
Small sized	634.13	2160.90	932.72	820.42	1136.65	1355.50	1173.39
Large sized	640.59	2715.07	1006.15	874.42	1313.49	1822.79	1395.42
Mean	**637.36**	**2437.99**	**969.44**	**847.42**	**1225.07**	**1589.15**	1284.40
PVC pots							
Small sized	662.40	3143.25	1402.73	1311.26	2435.47	2909.18	1977.38
Large sized	810.80	3961.62	2867.08	1932.76	3024.79	3432.63	2671.61
Mean	**736.60**	**3552.44**	**2134.91**	**1622.01**	**2730.13**	**3170.91**	2324.50
Earthen pots							
Small sized	787.08	4129.60	2983.37	2802.79	3501.55	3763.72	2994.69
Large sized	1569.17	4932.06	3286.74	3160.46	4316.59	4857.38	3687.07
Mean	**1178.13**	**4530.83**	**3135.06**	**2981.63**	**3909.07**	**4310.55**	3340.88
Mean for media and containers							
C_1	637.36	2437.99	969.44	847.42	1225.07	1589.15	1284.40
C_2	736.60	3552.44	2134.91	1622.01	2730.13	3170.91	2324.50
C_3	1178.13	4530.83	3135.06	2981.63	3909.07	4310.55	3340.88
General mean	**850.69**	**3507.08**	**2079.80**	**1817.02**	**2621.42**	**3023.53**	2316.59
CD for factor A*= 132.61		Factor B*= 93.78			Factor C* = 76.57		
A × B = 229.69	A × C = 187.54		B × C = 132.61		A × B × C = 324.84		

*Factor A = Substrate, Factor B = Containers, Factor C = Size.

The various substrates and containers of different size caused significant differences in total root length per plant (Table 5). The interactions between substrate and containers, substrate and container size, containers and size and that of all the factors of the variation were found significant. Among the different substrates tried, the S_1 substrate gave maximum total root length followed by S_5 and the minimum total root length was found in control (soil). Among different container used, the earthen pot gave maximum (3340.88 cm)total root length followed by PVC pot (2324.50 cm) and the minimum (1284.40 cm) was found in polyethylene bag. Conclusively, the strawberry plants grown with $S_{1,}$ substrate in large sized pots produced maximum total root length (4932.06 cm) and were found best among all the treatment combinations investigated. This may be a results of the easily availability of nutrition and water, porosity and more space for root growth. This investigation was supported by Klamkowski*et al.* (2006), who also reported that maximum total root length was recorded with perlite used as soilless substrate with the combination of sandy loam soil under column system.

The present findings highlight the putative use of organic medium i.e. cocopeat, perlite and vermicompost as substrate medium in strawberry culture. The performance of plants grown on cocopeat + perlite + vermicompost (3:1 : 1) is markedly influenced by the media followed by the cocopeat + perlite + vermicompost (4:1:2). It may be due to the alteration of physicochemical properties (such as porosity, water content and air capacity) of raw material and hence the air and water balance in the root environment. Further research study is necessary for the complete exploitation of the putative use of substrate mixtures as pure or composted material and of its ability to improve physico-chemical properties as substrate medium, identifying the exact ratio mixed into substrates as well as appropriate container type (to improve hydraulic properties of the media) for hydroponically grown crops.

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