Impact of diverse substrate combinations and container types on strawberry quality in soilless cultivation

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ABSTRACT

This study investigated the impact of various growing substrate combinations and container types on the quality attributes of Sweet Charlie strawberries grown in a soilless cultivation system. The experiment, conducted in a hi-tech greenhouse over two consecutive seasons (2013-14 and 2014-15), evaluated seven distinct substrate combinations and three container types: polyethylene bags, PVC pots and earthen pots. Key quality parameters assessed included TSS-acid ratio, total sugars, reducing sugars, ascorbic acid and anthocyanin content. Results consistently showed that both substrate combinations and container types significantly influenced the evaluated quality attributes. Substrate cocopeat + perlite + vermicompost in a 4:1:2 ratio generally led to the highest TSS-acid ratio, total sugars and reducing sugars in both seasons. Control consistently resulted in the lowest values for these parameters. For container types, earthen pots were consistently associated with the highest TSS-acid ratio, total sugars and reducing sugars. Interestingly, polyethylene bags yielded the highest ascorbic acid content. The interaction between substrates and containers was found to be non-significant for TSS-acid ratio and ascorbic acid, indicating that the best substrate and container effects operated independently. However, significant interactions were observed for total sugars and reducing sugars. These findings highlight the critical role of selecting appropriate growing media and container designs for optimizing strawberry fruit quality in soilless cultivation.

Keywords: Strawberry; soilless cultivation; substrate; container; quality attributes

INTRODUCTION

The strawberry (*Fragaria* × *ananassa* Duch) is one of the most widely grown soft fruits in the world because of its high heterozygosity, rich genetic variety, and environmental adaptability. Although it grows well in temperate climates, tropical and subtropical areas can also produce it with success. As a traditional short-day plant, it grows best at temperatures between 22 and 25°C during the day and between 7 and 13°C at night (De and Bhattacharjee 2008). China is leading with approximately 3.4 million tonnes strawberry fruit production followed by the United States of America (1.31 million tonnes) and Turkey (728.1 kg tonnes) (Anon 2025a).

In India, the cultivated area under strawberry was nearly 3.31 thousand hectares with production of 19.84 thousand MT and productivity of 5.99 MT per hectare in 2020-21 (Anon 2023). Maharashtra is the leading state in the production of strawberry and it is cultivated in Himachal Pradesh, Uttrakahand, Jammu and Kashmir, West Bengal (Darjeeling hills) and Haryana (Sharma and Budiyala 1980). In Haryana, around 231 hectares of land is under strawberry cultivation in Hisar district which has emerged as a strawberry hub of the north India and the second largest producer of the exotic fruit after Mahabaleshwar in Maharashtra (Anon 2025b). Strawberry cultivation in northern India is picking up fast due to availability of market in Delhi and quick returns.

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 pests, the use of artificial media is gaining popularity and number of soilless substrates/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, has 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). A number of pots of different sizes and types are available in the market for different crops. Strawberry has large number of roots but more than 90 per cent 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 (Sharma et al 2015).

MATERIAL and METHODS

Experimental site and material

The experiment was conducted at hi-tech greenhouse of Department of Horticulture, CCS Haryana Agricultural University, Hisar, Haryana. Three substrates cocopeat, perlite and vermicompost were used (by volume) to create the different treatments in different proportions (Table 1, Fig 1). Three types of containers were used: C_1 (Polyethylene bags), C_2 (PVC pots) and C_3 (Earthen pots). The soil and substrate mixtures were tested for EC, pH, organic carbon and organic matter at the initial and final stage of the experiment, whereas, bulk density, particle density, total porosity, moisture content at field capacity and maximum water holding capacity were analysed at the initial stage of the experiment (Tables 2, 3).

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 of excess water. The transplanted plants were kept under uniform condition in polyhouse during the study period. The standard and uniform fertilizer solution was used for whole course of investigations. The quantity of fertilizer salts was dissolved into two 100-liter stock solution tanks. The vegetative formulations were used from plant establishment until fruit set on the first truss then a fruiting formulation introduced. The fruiting formulation maintains higher level of potassium for fruit growth and quality. The fertigation system was open drip irrigation with no circulation, using 2 liter per hour capacity in line lateral drippers installed on each pot.

The ratio of total soluble solids to acid was obtained by dividing the total soluble solids with total acid, while, ascorbic acid was estimated by using the procedure given in Anon (2005). The anthocyanin content was estimated as per the method suggested by Harborne (1973) and sugars as per the method described by Hulme and Narain (1931).

Statistical analysis

The data were analyzed according to the procedure for analysis of completely randomized design (CRD) as given by Panse and Sukhatme (1985). The results were statistically analyzed with the help of a windows-based computer package OPSTAT (Sheoran et al 1998).

RESULTS and DISCUSSION

Table 4 depicts the effect of different substrate combinations and containers on TSS-acid ratio, total sugars, reducing sugars, ascorbic acid and anthocyanin contents on strawberry cv Sweet Charlie.

TSS-acid ratio: TSS-acidity ratio was significantly influenced by various substrate combinations and containers during both the seasons, however, the interactions between substrates and containers were

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

Substrate code	Substrate used	Ratio
S_1	Cocopeat + perlite + vermicompost	(2:1:1)
S_2	Cocopeat + perlite + vermicompost	(3:1:1)
S_3	Cocopeat + perlite + vermicompost	(4:0:1)
S_4	Cocopeat + perlite + vermicompost	(4:1:0)
S_5	Cocopeat + perlite + vermicompost	(4:1:1)
S_6	Cocopeat + perlite + vermicompost	(4:1:2)
S_7 (Control)	Soil	-

Table 2. Initial and final EC, pH and organic carbon of substrates used in the experiment

Substrate	EC (dS/m)		pH		Organic carbon (%)		Organic matter (%)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
S_1	0.91	0.15	6.44	7.32	21.14	16.26	36.45	28.03
S_2	0.99	0.21	6.20	7.04	19.76	26.48	34.07	45.65
S_3	1.14	0.25	6.39	6.59	42.51	30.10	73.29	51.89
S_4	1.00	0.37	5.53	6.30	43.75	43.16	75.43	74.41
S_5	0.83	0.60	5.77	6.25	33.84	36.52	58.34	62.96
S_6	1.08	0.12	6.03	6.94	30.72	23.60	52.96	40.69
S_7	0.48	0.45	7.80	7.93	0.45	0.44	0.78	0.76

S_1: Cocopeat + perlite + vermicompost (2:1:1), S_2: Cocopeat + perlite + vermicompost (3:1:1), S_3: Cocopeat + perlite + vermicompost (4:0:1), S_4: Cocopeat + perlite + vermicompost (4:1:0), S_5: Cocopeat + perlite + ermicompost (4:1:1), S_6: Cocopeat + perlite + vermicompost (4:1:2), S_7 (Control): Soil

Table 3. Physical properties of substrates used in the experiment

Substrate	Bulk density (g/cm³)	Particle density (g/cm³)	Total porosity (%)	Moisture content at field capacity (%)	Maximum water holding capacity (%)
S_1	0.320	1.57	79.62	180.73	139.87
S_2	0.256	1.23	79.19	155.52	209.22
S_3	0.205	1.51	86.42	142.52	249.15
S_4	0.096	0.91	89.45	254.60	403.56
S_5	0.235	1.33	82.33	170.55	137.58
S_6	0.302	1.47	79.46	103.32	134.04
S_7	1.47	2.65	0.45	17.63	24.88

S_1: Cocopeat + perlite + vermicompost (2:1:1), S_2: Cocopeat + perlite + vermicompost (3:1:1), S_3: Cocopeat + perlite + vermicompost (4:0:1), S_4: Cocopeat + perlite + vermicompost (4:1:0), S_5: Cocopeat + perlite + ermicompost (4:1:1), S_6: Cocopeat + perlite + vermicompost (4:1:2), S_7 (Control): Soil

found non-significant. A perusal of the data indicates that higher TSS-acidity ratio was observed under S_6 {Cocopeat + perlite + vermicompost (4:1:2)} (10.11 and 9.60) and S_2 {Cocopeat + perlite + vermicompost (3:1:1)} (9.57 and 8.96) during 2013-14 and 2014-15 respectively, which were statistically at par. The least value of TSS-acid ratio was observed in S_7 (Control) (Soil) (7.36 and 7.28) at par with S_4 {Cocopeat + perlite + vermicompost (4:1:0)} (7.92 and 7.95) during 2013-14 and 2014-15 respectively. The strawberry fruits harvested from C_3 (Earthen pots) (9.94 and 9.48) gave highest TSS-acid ratio followed by C_1 (Polyethylene bags) (8.71 and 8.49), whereas, minimum (7.77 and 7.52) was recorded in C_2 (PVC pots).

Table 4. Effect of different substrate combinations and containers on TSS-acid ratio, total sugars, reducing sugars, ascorbic acid and anthocyanin content in strawberry cv Sweet Charlie

Substrate	Quantity							
	2013-14				2014-15			
	(C_1)	(C_2)	(C_3)	Mean	(C_1)	(C_2)	(C_3)	Mean
TSS-acid ratio								
S_1	8.90	8.06	10.52	9.16	9.04	7.82	9.79	8.88
S_2	9.34	8.45	10.93	9.57	8.96	7.93	10.00	8.96
S_3	8.71	7.62	9.53	8.62	8.21	7.34	9.39	8.31
S_4	7.78	7.07	8.92	7.92	7.91	7.08	8.86	7.95
S_5	8.74	7.89	10.03	8.89	8.43	7.40	9.65	8.49
S_6	10.06	8.97	11.31	10.11	9.71	8.47	10.63	9.60
S_7	7.42	6.34	8.33	7.36	7.16	6.62	8.07	7.28
Mean	8.71	7.77	9.94		8.49	7.52	9.48	
Total sugars (%)								
S_1	5.44	5.23	6.17	5.61	5.74	5.41	5.98	5.71
S_2	5.87	5.54	6.53	5.98	5.86	5.57	6.18	5.87
S_3	5.40	5.15	5.78	5.44	5.64	5.27	5.87	5.59
S_4	5.32	5.10	5.72	5.38	5.57	5.21	5.85	5.54
S_5	5.72	5.39	6.38	5.83	5.81	5.49	6.11	5.80
S_6	6.00	5.68	6.68	6.12	6.08	5.65	6.37	6.03
S_7	5.21	4.83	5.47	5.17	5.35	4.93	5.54	5.27
Mean	5.57	5.27	6.10		5.72	5.36	5.98	
Reducing sugars (%)								
S_1	4.52	4.35	5.12	4.66	4.76	4.49	4.96	4.74
S_2	4.88	4.60	5.42	4.97	4.86	4.62	5.13	4.87
S_3	4.49	4.28	4.80	4.52	4.68	4.37	4.87	4.64
S_4	4.42	4.23	4.75	4.47	4.62	4.32	4.85	4.60
S_5	4.75	4.47	5.29	4.84	4.82	4.55	5.07	4.81
S_6	4.99	4.72	5.55	5.08	5.04	4.69	5.28	5.00
S_7	4.32	4.03	4.55	4.30	4.44	4.09	4.60	4.38
Mean	4.62	4.38	5.07		4.74	4.45	4.97	
Ascorbic acid (mg/100 g)								
S_1	42.65	41.31	41.76	41.91	42.46	40.12	41.47	41.35
S_2	40.76	39.01	40.08	39.95	41.44	38.31	39.53	39.76
S_3	39.79	37.48	38.95	38.74	40.15	38.09	38.71	38.98
S_4	39.12	36.72	38.22	38.02	38.06	36.47	37.07	37.20
S_5	39.68	37.10	38.45	38.41	39.65	37.60	38.26	38.50
S_6	42.45	40.53	41.54	41.50	41.89	38.97	40.91	40.59
S_7	38.89	35.63	38.05	37.52	37.75	35.24	35.95	36.31
Mean	40.48	38.25	39.58		40.20	37.83	38.84	
Anthocyanin (mg/100 g)								
S_1	42.62	46.32	47.82	45.59	44.10	47.28	48.84	46.74
S_2	42.10	45.00	46.90	44.67	42.96	46.32	47.85	45.71
S_3	41.24	43.34	44.89	43.16	41.39	43.08	44.61	43.02
S_4	40.76	42.66	44.63	42.68	40.19	41.55	43.65	41.79
S_5	41.62	43.60	45.99	43.74	41.74	43.73	45.81	43.76
S_6	41.77	44.30	46.24	44.10	42.77	44.55	46.92	44.75
S_7	39.24	42.04	43.73	41.67	38.42	40.60	41.40	40.14
Mean	41.33	43.89	45.74		41.65	43.85	45.58	

$CD_{0.05}$	TSS-acid ratio		Total sugars (%)		Reducing sugars (%)		Ascorbic acid (mg/100 g)		Anthocyanin (mg/100 g)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Substrate	0.86	0.68	0.15	0.14	0.15	0.13	2.48	2.67	2.10	2.52
Container	0.56	0.45	0.10	0.09	0.09	0.18	1.63	1.75	1.38	1.65
Substrate × Container	NS	NS	0.25	0.24	0.23	0.22	NS	NS	3.65	NS

S_1: Cocopeat + perlite + vermicompost (2:1:1), S_2: Cocopeat + perlite + vermicompost (3:1:1), S_3: Cocopeat + perlite + vermicompost (4:0:1), S_4: Cocopeat + perlite + vermicompost (4:1:0), S_5: Cocopeat + perlite + ermicompost (4:1:1), S_6: Cocopeat + perlite + vermicompost (4:1:2), S_7 (Control): Soil; C_1: Polyethylene bags, C_2: PVC pots, C_3: Earthen pots; NS: Non-significant

Cocopeat block | Moistening of cocopeat | Cocopeat after meshing | Perlite | Vermicompost | Mixing of substrates by volume

Fig 1. Substrates used in the experiment and their preparation

Total sugars: Total sugars were significantly affected by various substrates and containers and their interactions. In the year 2013-14, maximum total sugars were observed in the fruits harvested from S_6 (6.12%) and S_2 (5.98%), which were at par and minimum (5.17%) in S_7. However, during 2014-15 again S_6 resulted in maximum total sugars (6.03%) over other substrates. The strawberry fruits obtained from C_3 contained highest (6.10 and 5.98%) total sugars followed by C_1 (5.57 and 5.72%), whereas, minimum total sugars (5.27 and 5.36%) were recorded under C_2 during 2013-14 and 2014-15 respectively. Treatments S_6C_3 (6.68 and 6.37%) and S_2C_3 (6.53 and 6.18%) resulted in significantly highest total sugars over other treatment combinations during 2013-14 and 2014-15 respectively and remained at par in individual years.

Reducing sugars: S_6 (5.08 and 5.00%) and S_2 (4.97 and 4.87%) significantly increased the reducing sugars of fruits over rest of the treatments during 2013-14 and 2014-15 respectively and were at par in both the years. The minimum reducing sugars (4.30 and 4.38%)

were recorded in S_7. Amongst the containers used, the highest reducing sugars content was recorded in the fruits in C_3 (5.07 and 4.97%) followed by C_1 (4.62 and 4.74%) and lowest (4.38% and 4.45%) in C_2 during 2013-14 and 2014-15 respectively. In 2013-14, S_6C_3 (5.55%) and S_2C_3 (5.42%) resulted in maximum reducing sugars and were at par as against minimum in S_7C_2 (4.03%) and S_4C_2 (4.23%), which were also at par. In 2014-15, S_6C_3 (5.28%), S_2C_3 (5.13%) and S_5C_3 {Cocopeat + perlite + ermicompost (4:1:1) (Earthen pots)} (5.07%) lead to maximum reducing sugars, which were at par. Minimum reducing sugars were, however, recorded in S_7C_2 (4.09%).

The increased TSS and sugars in fruits could be attributed to the increased leaf area, which in turn might have favoured photosynthetic rate, translocation and accumulation of sugars and metabolites in fruits under soilless culture. Similar results were obtained by Ayesha et al (2011), who reported maximum TSS and better taste, when grown in soilless culture compared to soil in strawberry. In the present study, significant difference in various soilless media were also observed with respect to TSS, TSS-acid ratio and sugars. This might be due to the reason that different proportions of cocopeat + perlite + vermicompost changed the physical and chemical properties of the substrates, which significantly influenced the quality characteristics in strawberry. The results are also in line with the findings of Jafarnia et al (2010), Ameri et al (2012) and Sharma and Godara (2019), who reported the influence of various substrates on TSS and sugar content. However, the contrasting results were obtained by Fernandez et al (2006) and Cantliffe et al (2008), who reported that the main characteristics related to nutritional quality viz TSS, organic acids, soluble sugars and minerals differed non-significantly under soil and soilless culture systems and media.

Ascorbic acid: In 2013-14, the maximum ascorbic acid content (41.91, 41.50 and 39.95 mg/100 g) was recorded in the fruits obtained from S_1 {Cocopeat + perlite + vermicompost (2:1:1)}, S_6 and S_2 respectively, which were statistically at par; while the minimum (37.52, 38.02, 38.41 and 38.74 mg/100 g) was obtained in S_7, S_4, S_5 and S_3 (S_3: Cocopeat + perlite + vermicompost (4:0:1) respectively, which were at par and also at par with S_2 (39.95 mg/100 g). Among containers, C_1 (40.48 mg/100 g) and C_3 (39.58 mg/ 100 g) resulted in higher ascorbic acid content and were par. Lower ascorbic acid content was recorded in C_2 (38.25 mg/100 g) which was also at par wtih C_3 (39.58 mg/100 g). There was no significant effect of the interaction of containers and substrates on ascorbic acid content.

In 2014-15, maximum ascorbic acid content was seen in S_1 (41.35 mg/100 g), S_6 (40.59 mg/100 g), S_2 (39.76 mg/100 g) and S_3 (38.98 mg/100 g), all being at par as compared to S_7 (36.31 mg/100 g), S_4 (37.20 mg/100 g) and S_5 (38.50 mg/100 g), which were at par and also at par with S_3 (38.98 mg/100 g). C_1 (40.20 mg/100 g) and C_3 (38.84 mg/100 g) gave higher ascorbic acid content and were at par, than C_2 (37.83 mg/100 g) which was also at par with C_3 (38.84 mg/100 g). There was no interaction effect of containers and substrates in 2014-15 also.

This might be due to substrate physico-chemical properties alteration by mixing of organic (cocopeat and vermicompost) and inorganic (perlite) substrates, which may have resulted on total content of vitamin C and fruit quality. These results are in close conformity with the findings of Hassan et al (2011), who also reported maximum vitamin C content in the strawberry fruits produced using coconut husk and lowest from soil cultivation. The increase in ascorbic acid content could be due to the acceleration of growth and fruiting and possible physiological processes like synthesis of carbohydrates in the plant system (Sharma et al 2018).

Anthocyanin content: During 2013-14, the maximum anthocyanin content (45.59, 44.67, 44.10 and 43.74 mg/100 g) was observed in S_1, S_2, S_6 and S_5 respectively, which were at par and minimum (41.67, 42.68 and 43.16 mg/100 g) in S_7, S_2 and S_1 respectively, which were also at par with S_5 (43.74 mg/100 g). Among containers, C_3 (45.74 mg/100 g) resulted in maximum and C_1 (41.33 mg/100 g) in minimum anthocyanin content. In the interaction effect, S_1C_3 (47.82 mg/100 g), S_2C_3 (46.90 mg/100 g), S_1C_2 (46.32 mg/100 g), S_6C_3 (46.24 mg/100 g), S_5C_3 (45.99 mg/100 g), S_2C_2 (45.00 mg/100 g), S_3C_3 (44.89 mg/100 g), S_4C_3 (44.63 mg/100 g) and S_6C_2 (44.30 mg/100 g) resulted in maximum anthocyanin content, which were at par. On the other hand, minimum anthocyanin content was observed in the combinations S_7C_1 (39.24 mg/100 g), S_4C_1 (40.76 mg/100 g), S_3C_1 (41.24 mg/100 g), S_5C_1 (41.62 mg/ 100 g), S_6C_1 (41.77 mg/100 g), S_7C_2 (42.04 mg/100 g), S_2C_1 (42.10 mg/100 g) S_1C_1 (42.62 mg/100 g) and S_4C_2 (42.66 mg/100 g), which were at par.

In 2014-15, S_1, S_2 and S_6 exhibited maximum anthocyanin content (46.74, 45.71 and 44.75 mg/100 g respectively) and were at par. Minimum content (40.14 and 41.79 mg/100 g) was observed in S_7 and S_4 respectively, which were at par. On the other hand, C_3 (45.58 mg/100 g) resulted in maximum and C_1 (41.65 mg/100 g) the minimum anthocyanin content. The interaction effect of containers and substrates was non-significant

The anthocyanin pigment increase in berries might be due to tendency of the anthocyanin content increase with increased sugar metabolism during fruiting period in soilless culture as compared to soil. Ghazvini et al (2007) and Ameri et al (2012) found similar results, who reported that different substrates had significant effect on anthocyanin content in strawberry. Similarly, Schmitzer and Stampar (2009) reported that phenolic compounds, especially anthocyanin, depend on substrate pH, which gradually increase with the decrease in pH content of growing media. But the results are not in agreement with the findings of Paraskevopoulou-Paroussi et al (1995), who reported that the soil and soilless culture had non-significant effect on anthocyanin pigment in strawberry.

In the present study, the highest TSS-acid ratio, total sugars, reducing sugars were observed in the fruits harvested from earthen pots, whereas, maximum ascorbic acid content was recorded in the fruits harvested from polyethylene bag. The results are more or less similar with the findings of Hassan et al (2011), who also reported that the quality characteristics in strawberry were significantly influenced by different growing containers.

CONCLUSION

The comprehensive investigation into the influence of varied substrate combinations and container types on Sweet Charlie strawberry quality in a soilless cultivation system yielded clear insights into optimal growing conditions. It was consistently observed that substrate cocopeat + perlite + vermicompost (4:1:2) was associated with superior TSS-acid ratio, total sugars and reducing sugars across both study seasons. Conversely, the control substrate consistently resulted in the lowest values for these quality indicators, emphasizing the benefits of engineered soilless media. Regarding containers, earthen pots were found to significantly enhance TSS-acid ratio, total sugars and reducing sugars, making them a preferred choice for these specific quality traits. Notably, polyethylene bags were instrumental in promoting higher ascorbic acid content in the fruits. While no significant interaction effects between substrates and containers were found for TSS-acid ratio and ascorbic acid, specific substrate-container combinations were particularly effective for total and reducing sugars. Ultimately, these findings offer valuable guidance for growers, indicating that careful selection of both growing substrate and container type is paramount for maximizing strawberry quality in soilless systems, potentially leading to more flavourful and nutritious harvests.

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