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

**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 S2 (cocopeat + perlite + vermicompost, 3:1:1) followed by S1 (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.

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

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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 borned 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 (C₁)

| CS₁ | 16 × 16 cm |
| CS₂ | 20 × 20 cm |

PVC Pots (C₂)

| CS₁ | 15 × 15 cm |
| CS₂ | 25 × 25 cm |

Earthen Pots (C₃)

| CS₁ | 15 × 15 cm |
| CS₂ | 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 S₂ produced maximum number of leaves (10.45 and 15.42) per plant followed by S₁ (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 CS₂ PVC pots with S₂ 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 S₂ 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 (S₇). 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 S₂ 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 S₂ resulted maximum plant height (15.26 cm and 16.27 cm) followed by S₁ (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 C₁ (polyethylene bags). Thus, strawberry plants grown with S₂ 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 CS₂ 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 S₂ gave highest plant spread (27.43 cm and 30.24 cm) followed by S₁ (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 has been concluded that the strawberry plants were grown in S₂ with CS₂ 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 S₂C₃CS₂ (31.37 cm) and S₂C₁CS₂ (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.      | S₁             | cocopeat + perlite + vermicompost  | (2:1:1) |
| 2.      | S₂             | cocopeat + perlite + vermicompost  | (3:1:1) |
| 3.      | S₃             | cocopeat + perlite + vermicompost  | (4:0:1) |
| 4.      | S₄             | cocopeat + perlite + vermicompost  | (4:1:0) |
| 5.      | S₅             | cocopeat + perlite + vermicompost  | (4:1:1) |
| 6.      | S₆             | cocopeat + perlite + vermicompost  | (4:1:2) |
| 7.      | S₇ (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 (C1) | PVC Pots (C2) | Earthen Pots (C3) |
|                  | CS1 | CS2 | Mean | CS1 | CS2 | Mean | CS1 | CS2 | Mean |
| S1               | 8.85 | 9.75 | **9.30** | 9.50 | 11.42 | **10.46** | 8.92 | 10.87 | **9.89** |
| S2               | 8.92 | 10.53 | **9.72** | 9.93 | 12.43 | **11.18** | 9.53 | 11.38 | **10.46** |
| S3               | 7.95 | 8.62 | **8.28** | 8.15 | 10.35 | **9.25** | 8.03 | 9.13 | **8.58** |
| S4               | 7.72 | 8.22 | **7.97** | 7.95 | 9.03 | **8.49** | 7.77 | 8.88 | **8.32** |
| S5               | 8.43 | 9.25 | **8.84** | 9.07 | 10.45 | **9.76** | 8.85 | 9.52 | **9.18** |
| S6               | 8.58 | 9.50 | **9.04** | 9.30 | 11.05 | **10.17** | 9.15 | 10.17 | **9.66** |
| S7 (Control)     | 7.23 | 8.00 | **7.62** | 7.52 | 8.83 | **8.18** | 7.45 | 8.13 | **7.79** |
| Mean             | **8.24** | **9.12** | **8.68** | **8.77** | **10.51** | **9.64** | **8.53** | **9.73** | **9.13** |
| CD (P = 0.05)    | Substrate = 0.20; Container = 0.13; Container size = 0.11; Substrate x Container = 0.35 |
|                  | Container xContainer size = 0.19; Substrate x Container x Container size = N.S. |
| 2014-2015        |                |              |
| S1               | 12.17 | 15.42 | **13.79** | 14.75 | 17.50 | **16.12** | 13.27 | 15.93 | **14.60** |
| S2               | 13.17 | 15.67 | **14.42** | 15.05 | 18.43 | **16.74** | 14.18 | 16.05 | **15.12** |
| S3               | 10.10 | 12.60 | **11.35** | 11.85 | 16.05 | **13.95** | 11.40 | 13.23 | **12.32** |
| S4               | 9.88  | 10.80 | **10.34** | 10.60 | 12.55 | **11.57** | 10.33 | 11.28 | **10.81** |
| S5               | 10.45 | 14.57 | **12.51** | 13.07 | 16.28 | **14.67** | 11.17 | 14.78 | **12.98** |
| S6               | 11.72 | 14.85 | **13.28** | 14.63 | 17.45 | **16.04** | 12.83 | 15.70 | **14.27** |
| S7 (Control)     | 8.40  | 9.45  | **8.93**  | 9.26  | 11.05 | **10.15** | 9.05  | 10.36 | **9.70**  |
| Mean             | **10.84** | **13.34** | **12.09** | **12.74** | **15.62** | **14.18** | **11.75** | **13.91** | **12.83** |
| CD (P = 0.05)    | Substrate = 0.21; Container = 0.14; Container size = 0.11; Substrate x Container = 0.37 |
|                  | Container xContainer size = 0.20; Substrate x Container x 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 (C₁)  |              |
|                        | PVC Pots (C₂)           |              |
|                        | Earthen Pots (C₃)       |              |
|                        | CS₁   | CS₂   | Mean | CS₁   | CS₂   | Mean | CS₁   | CS₂   | Mean |
| S₁                     | 8.01  | 8.91  | 8.46 | 8.30  | 9.24  | 8.77 | 7.58  | 8.69  | 8.14 |
| S₂                     | 8.76  | 9.39  | 9.08 | 9.34  | 9.85  | 9.60 | 8.72  | 9.04  | 8.88 |
| S₃                     | 7.50  | 8.04  | 7.77 | 7.54  | 8.26  | 7.90 | 6.76  | 7.75  | 7.25 |
| S₄                     | 7.11  | 7.93  | 7.52 | 7.26  | 8.15  | 7.71 | 6.57  | 7.48  | 7.02 |
| S₅                     | 7.67  | 8.55  | 8.11 | 7.77  | 8.73  | 8.25 | 7.29  | 7.88  | 7.58 |
| S₆                     | 7.79  | 8.76  | 8.28 | 7.88  | 8.78  | 8.33 | 7.49  | 7.95  | 7.72 |
| S₇ (Control)           | 6.93  | 7.34  | 7.13 | 7.11  | 7.39  | 7.25 | 6.54  | 7.22  | 6.88 |
| Mean                   | 7.68  | 8.42  | 8.05 | 7.89  | 8.63  | 8.26 | 7.28  | 8.00  | 7.64 |
| 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 - 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) | 2013-2014 | Overall mean |
|-------------------|---------------|-----------|-------------|
|                   | Polyethylene Bags (C₁) | PVC Pots (C₂) | Earthen Pots (C₃) |
|                   | CS₁ | CS₂ | Mean | CS₁ | CS₂ | Mean | CS₁ | CS₂ | Mean |
| S₁                | 13.18 | 15.17 | **14.18** | 14.78 | 15.85 | **15.32** | 14.49 | 15.50 | **14.99** | 14.83 |
| S₂                | 14.22 | 15.40 | **14.81** | 15.07 | 16.60 | **15.83** | 14.76 | 15.54 | **15.15** | 15.26 |
| S₃                | 12.28 | 13.87 | **13.07** | 13.50 | 15.09 | **14.29** | 13.31 | 14.77 | **14.04** | 13.80 |
| S₄                | 12.22 | 13.17 | **12.70** | 13.13 | 14.81 | **13.97** | 12.88 | 13.57 | **13.23** | 13.30 |
| S₅                | 12.75 | 14.02 | **13.38** | 13.64 | 15.48 | **14.56** | 13.44 | 15.10 | **14.27** | 14.07 |
| S₆                | 13.01 | 14.27 | **13.64** | 14.09 | 15.76 | **14.93** | 13.98 | 15.13 | **14.56** | 14.38 |
| S₇ (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

| Substrates/ media | Containers (C) | 2014-2015 |
|-------------------|---------------|-----------|
|                   | Polyethylene Bags (C₁) | PVC Pots (C₂) | Earthen Pots (C₃) |
|                   | CS₁ | CS₂ | Mean | CS₁ | CS₂ | Mean | CS₁ | CS₂ | Mean |
| S₁                | 14.94 | 15.37 | **15.16** | 15.23 | 17.12 | **16.17** | 14.96 | 15.87 | **15.41** | 15.58 |
| S₂                | 15.29 | 16.25 | **15.77** | 15.97 | 17.79 | **16.88** | 15.66 | 16.63 | **16.15** | 16.27 |
| S₃                | 12.95 | 14.33 | **13.64** | 14.20 | 15.48 | **14.84** | 13.98 | 14.57 | **14.28** | 14.25 |
| S₄                | 12.78 | 13.87 | **13.32** | 13.82 | 15.36 | **14.59** | 13.68 | 14.27 | **13.97** | 13.96 |
| S₅                | 14.15 | 15.10 | **14.63** | 14.59 | 15.69 | **15.14** | 14.24 | 15.17 | **14.71** | 14.83 |
| S₆                | 14.41 | 15.28 | **14.84** | 15.19 | 16.40 | **15.80** | 14.83 | 15.65 | **15.24** | 15.29 |
| S₇ (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 (C₁) | PVC Pots (C₂) | Earthen Pots (C₃) |
|                  | CS₁  | CS₂  | Mean | CS₁  | CS₂  | Mean | CS₁  | CS₂  | Mean |
| S₁               | 22.46| 26.55| 24.51| 26.37| 28.84| 27.60| 23.99| 28.05| 26.02| 26.04 |
| S₂               | 25.90| 27.16| 26.53| 27.03| 29.19| 28.11| 26.86| 28.42| 27.64| 27.43 |
| S₃               | 21.29| 23.63| 22.46| 23.52| 25.24| 24.38| 23.19| 25.03| 24.11| 23.65 |
| S₄               | 19.33| 22.40| 20.86| 22.04| 24.47| 23.26| 21.48| 23.98| 22.73| 22.28 |
| S₅               | 21.40| 23.94| 22.67| 23.73| 26.04| 24.89| 23.43| 25.88| 24.66| 24.07 |
| S₆               | 22.32| 24.66| 23.49| 24.27| 27.80| 26.03| 23.87| 26.80| 25.33| 24.95 |
| S₇ (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 x Container = 0.48
Container x Container size = 0.26; Substrate x Container x Container size = 0.68

|                  | 2014-2015      |             |
|                  |                |             |
| S₁               | 26.04| 27.73| 26.88| 27.63| 30.77| 29.20| 26.43| 28.67| 27.55| 27.88 |
| S₂               | 28.31| 31.03| 29.67| 29.87| 31.64| 30.76| 29.22| 31.37| 30.30| 30.24 |
| S₃               | 21.51| 25.51| 23.51| 25.23| 28.36| 26.80| 25.07| 27.04| 26.06| 25.45 |
| S₄               | 20.86| 25.19| 23.03| 24.57| 26.30| 25.43| 24.39| 25.78| 25.08| 24.51 |
| S₅               | 25.04| 26.24| 25.64| 25.69| 28.61| 27.15| 25.61| 27.53| 26.57| 26.45 |
| S₆               | 25.49| 27.03| 26.26| 26.26| 28.86| 27.56| 26.08| 28.04| 27.06| 26.96 |
| S₇ (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 x Container = 0.43
Container x Container size = 0.23; Substrate x Container x 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) | 2013-2014 | Overall mean |
|-------------------|----------------|-----------|-------------|
|                   | Polyethylene Bags (C₁) | PVC Pots (C₂) | Earthen Pots (C₃) | |
|                   | CS₁ | CS₂ | Mean | CS₁ | CS₂ | Mean | CS₁ | CS₂ | Mean |
| S₁                | 15.57 | 16.78 | 16.18 | 17.04 | 17.71 | 17.38 | 16.22 | 17.16 | 16.69 | 16.75 |
| S₂                | 16.58 | 17.32 | 16.95 | 17.26 | 18.63 | 17.94 | 16.88 | 17.96 | 17.42 | 17.44 |
| S₃                | 12.82 | 14.87 | 13.85 | 14.69 | 15.46 | 15.07 | 13.98 | 15.20 | 14.59 | 14.50 |
| S₄                | 11.76 | 14.51 | 13.14 | 13.50 | 14.93 | 14.21 | 12.88 | 14.82 | 13.85 | 13.73 |
| S₅                | 13.97 | 15.94 | 14.95 | 15.20 | 16.29 | 15.75 | 14.34 | 15.98 | 15.16 | 15.29 |
| S₆                | 14.86 | 16.46 | 15.66 | 15.71 | 17.57 | 16.64 | 15.33 | 16.95 | 16.14 | 16.15 |
| S₇ (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

| Substrates/ media | Containers (C) | 2014-2015 | Overall mean |
|-------------------|----------------|-----------|-------------|
|                   | Polyethylene Bags (C₁) | PVC Pots (C₂) | Earthen Pots (C₃) | |
|                   | CS₁ | CS₂ | Mean | CS₁ | CS₂ | Mean | CS₁ | CS₂ | Mean |
| S₁                | 15.41 | 17.93 | 16.67 | 17.51 | 18.62 | 18.06 | 16.95 | 18.06 | 17.50 | 17.41 |
| S₂                | 16.87 | 18.14 | 17.51 | 18.08 | 19.32 | 18.70 | 17.80 | 18.41 | 18.10 | 18.10 |
| S₃                | 12.23 | 15.29 | 13.76 | 14.81 | 17.04 | 15.93 | 14.04 | 15.95 | 15.00 | 14.89 |
| S₄                | 12.06 | 14.59 | 13.33 | 14.33 | 15.29 | 14.81 | 13.82 | 15.09 | 14.46 | 14.20 |
| S₅                | 14.75 | 16.30 | 15.52 | 15.53 | 17.28 | 16.41 | 15.08 | 16.54 | 15.81 | 15.91 |
| S₆                | 15.09 | 17.17 | 16.13 | 16.70 | 18.02 | 17.36 | 15.52 | 17.81 | 16.66 | 16.72 |
| S₇ (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, S₂ resulted in maximum crown diameter (17.44 mm and 18.10 mm) followed by S₁ (16.75 mm and 17.41 mm) and S₆ (16.15 mm and 16.72 mm), while smallest crown diameter (11.61 mm and 12.34 mm) was observed in S₇ (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 CS₂ of PVC pots in combination with S₂, 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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