Research Article

Root Characteristics of Strawberry (*Fragaria* × *ananassa* Duch.) in Different Soil-less Growing Systems under Protected Cultivation

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Abstract

The present investigation was carried out to study the effect of different growing systems on roots of strawberry at Hi-tech green-house of CCS Haryana Agricultural University, Hisar (Haryana) during the year 2013-14. The strawberry (*Fragaria* × *ananassa* Duch.) plants grown hydroponically in different growing system (Soilless system in 75 and 90 mm PVC pipe with horizontal and vertical orientation) were studied in comparison to soil cultivation. The results indicate that plants grown in 90 mm PVC pipes with vertical soilless growing system produce maximum root surface area (6.00), root/ shoot ratio (0.67), number of secondary roots/ primary root (16.67), average length of primary (14.13 cm) and secondary roots (3.40 cm) and per cent increase in the length of most developed root (303.70), while maximum root density (3.03 kg/ m^3) and root length density (17.56 km/ m^3) were found in T_4 followed by T_5 (soilless vertical growing system in 90 mm PVC pipe). Maximum root area ratio (17×10^{-7}) was recorded from the plants grown in T_3 treatment followed by T_5 (12×10^{-7}), whereas maximum diameter of primary (0.627 mm) and secondary (0.243 mm) root was observed from soil cultivation (T_1). In future, these experimental results will prove very useful for vegetative and root growth of strawberry.

Keywords: Growing system, root density, root diameter, root surface area, strawberry

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Introduction

The modern cultivated strawberry (*Fragaria* × *ananassa* Duch.) is one of the widely distributed soft fruit crop in the world due to its genotypic diversity, highly heterozygous nature and broad range of environmental adaptations [1]. Popularity of strawberries can be judged from the fact that their production has increased to more than double over the past two and a half decades [2]. In India, the cultivated area under strawberry is nearly 15600 ha [3]. Strawberry cultivation in northern India picking up fast due to availability of market in Delhi and other cities and quickest returns in the short span. The soil cropping system traditionally used for the production of the strawberry crop but the main problem with its cultivation in soil is the loss of plants due to infection by soil-borne diseases caused by *Verticillium spp.* and *Phytophtora spp.* [4], nematodes and the occurrence of soil limited factors. The difficulty and cost of controlling soil-born pests and diseases, soil salinity, lack of fertile soil, water shortage, lack of space etc., have led to the development of substrates for soilless cultivation [5]. The properties of different materials used as soilless growing media exhibit direct and indirect effects on raising quality plant material [6], growth and productivity [7]. The plant culture using substrates allows a better control of the root environment [8]. Strawberry cultivation in soilless vertical sleeves allowed for better use of the area under cultivation and facilitates the crop management. The strawberry cultivation under the soilless column system is good alternative to the traditional system and showed significantly better effect on vegetative growth, yield [9] and root system [10].

Root development and distribution are important information for root–water and nutrient uptake studies in soil–plant systems [11]. However, intact root systems are costly and difficult to measure with a high degree of accuracy [12], because root distributions change with time as well as with different soil environment, plant species, growing seasons, climatic conditions, and other factors. Root characteristics such as length, mean diameter, surface area, and mass have been used to quantitatively and qualitatively describe root systems; however, comparisons made based on length rather than mass generally show greater differences. Several methods have been used to estimate root length [13]. Root length density distributions are often utilized to analyze soil–root–shoot–atmosphere interactions [14] and an important parameter to model water and nutrient movement in the vadose zone and to study soil–root–shoot–atmosphere interactions [15]. Total root surface area likely influences the kinetics of water and mineral uptake [16], and root diameter influences net ion influx into roots [17]. Keeping in view the above points, an attempt was made to determine the effect of different growing system on roots of strawberry (*Fragaria* × *ananassa* Duch.) cv. Sweet Charlie.

Materials and Methods

Experimental Site and Material

The experiment was conducted at Hi-tech greenhouse and Laboratory of Department of Horticulture, 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 during 2013-14 growing season to evaluate the root system of strawberry (Sweet Charlie) under different growing systems. The experiment was laid out in a completely randomized design with three replications and five treatment combinations, comprising of:

T_1: Soil cultivation (control)
T_2: Soilless system in horizontal PVC pipe (75 mm)
T_3: Soilless system in horizontal PVC pipe (90 mm)
T_4: Soilless system in vertical PVC pipe (75 mm)
T_5: Soilless system in vertical PVC pipe (90 mm)

A set of eight PVC pipes (2 m length) were installed in an area of 2.0 × 2.0 m in horizontal and 2.0 × 1.0 m in vertical hydroponic growing system. Seven plants were placed in each PVC pipe at 25 cm distance and in soil plants were planted at 30 × 30 cm. The PVC pipes were filled with a mixture of cocopeat + perlite + vermicompost (3:1:1). The irrigation system was open drip irrigation, no circulation, using two drippers with a flow rate of 8 liter/h at the top of each PVC pipe. The runners were planted during the second week of October directly in the substrates after treating with Carbendazim (1.4 g/ liter) and monocrotophos (1 ml/ liter).

Methodology and Observations Recorded

At the end of the growing season, each plant was uprooted and evaluated in terms of primary and secondary root diameter (D), number of secondary roots/ primary root, average length of primary and secondary root, per cent increase in the length of the most developed root, root density (RD), root length density (RLD), root area ratio (RAR), root/ shoot ratio, root surface area (RSA) and also determine the categories of root on length basis as a root parameter in this study.

$$\text{Root density (RD) kg/ m}^3 = MD/V \text{ [18]}$$

Where MD (kg) = Dry living root mass, V (m^3) = Volume of the corresponding soil cylinder (m^3)

$$\text{Root length density (RLD) km/m}^3 = LR/V \text{ [18]}$$

Where LR (km) =Root samples from each plant were collected and cleaned and total root length was then measured using a SCAN image analysis system, V (m^3) = Volume of the root permeated soil sample (m^3)

$$\text{Root area ratio (RAR)} = RLD \times RCSA \text{ [18]}$$

Where RCSA = Mean cross sectional area of a single root (m^2)

$$\text{Root surface area (RSA)} = \pi d \left(\frac{d}{2} + l\right) \text{[19]}$$

Where d = root diameter and l = average root length

Statistical Analysis

The data were analyzed according to the procedure for analysis of completely randomized design (CRD) as given by Panse and Sukhatme [20]. 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 [21].

Results and Discussion

The various treatments exerted significant influence on root growth in terms of root density, root length density, root area ratio, root surface area and root/ shoot ratio (**Table 1 and Figure 1**). Maximum root density (3.03 kg/ m^3) and root length density (17.56 km/ m^3) was recorded with plants grown in T_4 (soilless system in 75 mm vertical PVC pipe) treatment which was at par with T_5 (2.89 kg/ m^3) in case of root density. While, minimum root density (0.96 kg/ m^3) and root length density (4.33 km/ m^3) was recorded in T_1 (control) followed by T_3 (1.77 kg/ m^3 and 11.23 km/ m^3, respectively). Root area ratio of plants (4×10^{-7}) grown in soil was found lowest followed by T_2 (9×10^{-7}), whereas maximum root area ratio (17×10^{-7}) was recorded in plants grown in T_3. Root surface area (6.00) and root/ shoot ratio (0.67) was maximum when plants grown in T_5. While minimum root surface area (2.71) was observed in T_4 followed by T_1 (control) whereas, minimum root/ shoot ratio (0.25) was recorded in soil followed by T_3 (0.54) which was at par with T_4 (0.57) and T_2 (0.61).

Table 1 Effect of growing systems on roots of strawberry cv. Sweet Charlie

Treatments	Root density (kg/ m3)	Root length Density (km/ m3)	Root area ratio	Root surface area	Root/shoot ratio
T1	0.96	4.33	4×10^{-7}	3.78	0.25
T2	1.86	12.13	9×10^{-7}	4.77	0.61
T3	1.77	11.23	17×10^{-7}	5.35	0.54
T4	3.03	17.56	10×10^{-7}	2.71	0.57
T5	2.89	14.06	12×10^{-7}	6.00	0.67
CD (P = 0.05)	0.32	1.65	3×10^{-7}	0.59	0.09

Strawberry requires constant maintenance of optimum soil moisture to assure better crop establishment, growth and yield. These differences in roots can potentially be attributed to an altered source-sink relationship under deficit water supply causing more biomass allocation to roots [22]. As a consequence of the constant watering, the soil media and horizontal soilless media tend to compact diminishing the pores size and increasing the water retention and reducing the aeration capacity in the media [23] and the water excess may induce decrease oxygen in the aerial spaces of the substrate affecting the root development [24]. The more porosity favoured the growth and development of the root and may have been reflected in a higher root density verses the poor root density present in the strawberry plants gown in sand [9]. In maize (*Zea mays* L.) mild water stress resulted in increased root growth compared to well-watered conditions [25]. The enhancement of RLD with application and better nutrition of P has been widely reported [26]. Ebrahimi *et al.* [27] also reported the most shoot/root ratio from (peat + sand + perlite) treatment. Sharma *et al.* [28] observed significant effect of different growing systems on root/ shoot ratio in strawberry and found maximum root/ shoot ratio from the strawberry plants grown in vertical growing system.

Table 2 Effect of growing systems on roots of strawberry cv. Sweet Charlie

Treatments	Primary root Diameter (mm)	Secondary root diameter (mm)	Number of Secondary roots/ primary root	Average length of secondary root (cm)	Average length of primary root (cm)	Per cent increase in the length of most developed root
T1	0.627	0.243	7.33	2.63	7.50	198.55
T2	0.537	0.157	10.67	2.73	8.67	208.55
T3	0.463	0.157	12.00	2.90	10.97	252.08
T4	0.397	0.111	14.00	3.00	13.27	265.64
T5	0.569	0.133	16.67	3.40	14.13	303.70
CD (P = 0.05)	0.088	0.043	2.61	0.47	1.22	36.00

The average primary (0.627 mm) and secondary (0.243 mm) root diameter (**Table 2**) were recorded significantly higher in T_1 treatment where the plants were grown in soil (control). Whereas, minimum primary (0.397 mm) and secondary (0.111 mm) root diameter was recorded in the plants grown in soilless system in vertical PVC pipe (75 mm). Maximum number of secondary roots/ primary root (16.67), average length of secondary roots (3.40 cm), average length of primary root (14.13 cm) and per cent increase in the length of most developed root (303.70) were observed in the plants grown in vertical soilless growing system (90 mm) followed by T_4 treatment (14.00, 3.00 cm, 13.27 cm and 265.64, respectively) while, minimum were found from soil. Substrate has direct effect on development and performance of root system [24]. Similar decreases have also been reported earlier from different sites [29] and from different experimental plots [30]. Number of roots per plant was affected by the growing media and Perlite gave the best results in terms of number of primary roots per plant compared to soil [31].

Figure 1 (A) Conventional (Soil), (B) Horizontal, (C) Vertical growing systems, (D) Conventional growing system (Soil Plant), (E) Horizontal growing system (90 and 75mm PVC pipe), (F) Vertical growing system (90 and 75mm PVC pipe)

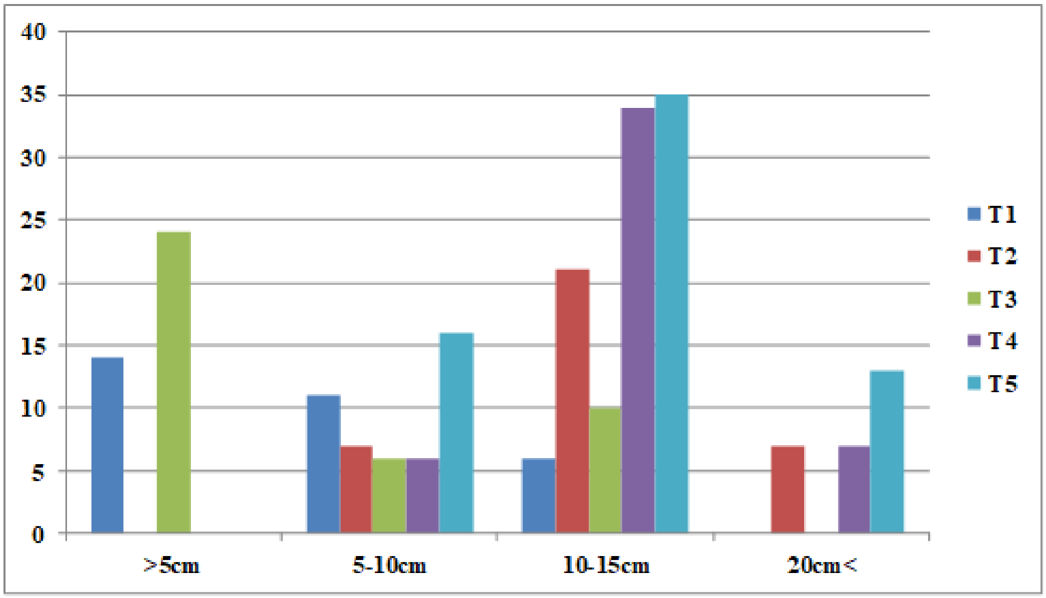

Figure 2 Effect of growing systems on root length (cm) categories (length basis) of strawberry cv. Sweet Charlie

The data presented in the **Figure 2** clearly shows that maximum number of root was observed in 10-15 cm length category and minimum number of roots present in more than 20 cm category. Maximum number of roots of less than 5 cm was recorded from T_3 treatment (24) followed by T_1 (soil), while, 5-10 cm length roots maximum found in T_5 (16) followed by T_1 (11). The maximum number of roots of 10-15 cm (35) and more than 20 cm was observed from T_5 (13). Root-length may be influenced by physical properties of substrates [32], the genotype [33], the growing season and development stage of the crop. Soilless system cause better exchange of elements especially cations inside substrate and distribute humidity properly around root, it is finally effective roots system formation of plant growth [34]. Increase in the length of root of strawberry in soilless cultivation system compared to the conventional system was also noticed by Ebrahimi *et al*. [27] and Sharma *et al.* [28].

Conclusion

According to results of this experiment, the performance of roots grown in soilless growing system (Horizontal and vertical) is markedly influenced by the media compared to the conventional system. It might be 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 investigation is needed to deepen the knowledge about the mechanism of action exerted by the different growing systems on strawberry roots.

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