



Effect of different soilless culture systems on growth, yield and quality of strawberry cv. STRAWBERRY FESTIVAL

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Abstract : The study was carried out to investigate the effect of different soilless culture systems (Open-trough, Lay-Flat-Bag and Verti-Gro) on growth, yield and fruit quality of strawberry cv. STRAWBERRY FESTIVAL. Good growth and performance in terms of yield and quality was better with Open-trough as compared to either Lay-Flat-Bag system and/or Verti-Gro system. Maximum leaf area (2478.66 cm²), largest crown diameter (33.75 mm), highest shoot fresh weight (60.97 g) and root fresh weight (16.50g), highest shoot dry weight (21.10 g) and root dry weight (5.74 g) was observed in Open-trough grown plants. Earliness in flowering (43 days) and highest TSS (10.61 °B) was also achieved in these plants as well as, highest number of flowers (37.00) and fruits (22.66) and total fruit weight per plant (281.83 g) along with higher marketable fruits (78.33 %). Lower titratable acidity (0.80 %) was observed in the fruits produced from the plants grown in Lay-Flat-Bag and Open-trough (0.83 %) systems. The better performance of the plants grown in open-trough and Lay-Flat-Bag systems were reflected by higher light incidence on leaf surface and photosynthesis rates as compared to those grown in Verti-Gro system.

Key Words : Strawberry Festival, Soilless culture

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INTRODUCTION

Strawberry (*Fragaria ananassa* Duch.) is a perennial, low-creeping, stoloniferous herb belonging to the family Rosaceae. It is basically a temperate fruit crop, widely distributed due to its genotypic diversity, high heterozygous nature and broad range of environmental adaptations (Sharma and Sharma, 2004). The cultivated strawberry of today's commercial market is result of cross between scarlet (*Fragaria virginiana* Duch.) and the chilean (*Fragaria chileonsis* Duch.) in early seventeen century in France (Galletta and Bringham, 1990). It has a unique, highly desirable taste and flavour and is one of the most popular fruits around the world (Sturmm *et al.*, 2003).

Soilless plant production has been practiced for several millennia and it permits crops to be grown where no suitable soil exists or where the soil is contaminated in some manner or other. Maximum yields are possible and this makes the system

economically feasible in high-density and expensive land areas. According to Takeda (2000), future growth of soilless culture will depend on the development of production systems and substrates that are competitive in costs and returns with conventional agriculture

Strawberry plant growth and fruit yield are dependent on the type of growing container used and the configuration or arrangement of the containers. The volume and dimensions of containers not only affect the physical characteristics such as aeration and water holding capacity of soilless media and plant growth, but also affect the cost, which may impact production costs (Cantliffe *et al.*, 2001). The decision to choose a growing system depends on its cost, ease of use, and ability to enhance fruit quality and yields. Growing containers should be arranged in such a way that sunlight is distributed evenly throughout the plant canopy and plant population density and yield are maximized.

Greenhouse structures are very expensive to set up, that

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is why it is very important to use the volume of the greenhouse to increase yield per square meter. The only way to utilize the greenhouse volume with strawberry production is to set up a vertical production system (Linsley-Noakes *et al.*, 2006). Planting density can be increased three times by using a vertical system as compared to horizontal systems (Ozeker *et al.*, 1999), but have problems with suboptimal environmental conditions in the lower sections, resulting in reduced yield and plant growth. Light intensity markedly affected strawberry plants growth and development. The irradiance reached the plants at the bottom of the columns was only 10 per cent ($<100 \mu\text{mol}/\text{m}^2/\text{s}$) of levels measured at the top. As a result, delayed growth occurred among the plants in the middle and bottom sections of the column. Many plants did not develop an optimal number of branch crowns and subsequently produced less fruit as compared with plants in the top section (Takeda, 2000). Similarly Durner (1999) reported that because of increasing irradiance, fruit yield of strawberry cv. SWEET CHARLIE increased with height in column. Albaho *et al.* (2008) compared three hydroponic techniques, *i.e.* nutrient film technique (NFT), A-shape aeroponics and a closed insulated pallet system (CIPS). Due to etiolation of crown in deep tray (15 cm deep), maximum plant height observed in NFT was negatively correlated with the other vegetative attributes. Plants grown in the aeroponics system recorded significantly higher leaf area and leaf number. Growing systems arranged in a single horizontal tier (usually in the north-south direction) accommodated high plant population densities up to 2.8 plants per ft^2 and since all plants are at the same height, light distribution was uniform (Paranjpe *et al.*, 2003). Radajewska and Aumiller (1997) evaluated strawberry cv. ELSANTA in a glasshouse by planting in peat filled bags placed on hanging gutters suspended 1.5 m aboveground and also placed on 30-cm-high cement platforms. Although total yield obtained from plants grown in both growing systems was similar, but higher economic yields were obtained from plants grown at 1.5m elevation. Reported by Cantliffe *et al.* (2007) that, higher early fruit number and fruit weight were obtained from plants grown in hanged Polygal troughs than plants grown in bag on gutter or bag on ground and a higher marketable fruit, fruit number and fruit weight was obtained from plants grown in bag on gutter and Polygal troughs than plants grown in bag on ground. And because of larger volume of bags (18 L) as compared to polygal trough (12 L), number of leaves and crown diameter of plants grown in bag on gutter and bag on ground was significantly higher.

Studies have shown that Verti-Gro systems are more productive (yield/ m^2) than the conventional soil based system due to much higher plant densities (El-Behairy *et al.*, 2001). It is important that not only the plant density is increased, but also the yield per square meter. Yield per square meter generally increased with an increase in planting density up to an

optimum beyond which an increase in planting density leads to a decrease in fruit quality (Dijkstra *et al.*, 1993). Villiers (2008) compared the A-shape and Verti-Gro systems on growth and yield of strawberry reported that higher photosynthetic active rate (PAR) was measured inside the A-shape system as compared to the Verti-Gro system. Therefore, plants in the A-shape production system produced significantly higher yields as compared to Verti-Gro system and time of anthesis to harvest was lesser in A-shape. Fruits produced in the A-shape system had an average soluble solids content of 8.7 per cent as compared to an average of 8.28 per cent in the Verti-Gro system. According to Durner (1999), a 40 g decrease in yield per plant was observed with every 30 cm decrease in planting height. This was attributed to shading effect on lower levels of the Verti-Gro system.

Among the column sizes (6, 7 and 8 pots/ column), columns with 6-pots performed significantly better than others in terms of biomass, yield and fruit quality (Al-Raisy *et al.*, 2010). As observed, the composition of the nutrient solution changed as it passed through the column and markedly affected the plant growth at the lower section (Jones, 1997). While in the A-shape growing system with same height and plant density, same problem did not notice (Durner, 1999).

MATERIALS AND METHODS

The present investigation was carried out in a passively ventilated greenhouse at the Division of Fruit Crops, Indian Institute of Horticultural Research (IIHR) Bangalore, India during 2010-11. The aim of this experiment was to determine the effects of several soilless culture systems on growth, yield and fruit quality of strawberry cv. STRAWBERRY FESTIVAL of grown in a passively ventilated greenhouse. The cultivar under study named Strawberry Festival is a short day cultivar developed in Florida Foundation Seed Producers, Inc., Greenwood, Florida USA which originated from seed produced by a hand pollinated cross between 'Rosa Linda' and 'Oso Grande.'

The systems employed were Lay-Flat-Bag placed on bench, Vertically Growing system (Verti-Gro) and Open-trough placed on bench.

Open-trough system :

The trench shaped troughs made (30 cm bottom wide, 40 cm top wide, 30 cm depth and 300 cm length) covered with black polyethylene sheet which accommodated 165 kg substrate and placed 60 cm apart of each other on metal made benches. The benches elevated from ground level at 90 cm. The length and breadth of benches were $3 \times 1.2\text{m}$ that the angle from the center of the bench down at a 2 per cent slope towards both the sides. The troughs filled with soilless media to a depth of 20 cm and the drip system for supplying nutrients solution, through emitters with 8 liter/hour discharging rate,

was placed.

Lay-Flat-Bag system :

115 kg capacity black polyethylene bags placed on metal made benches, elevated from ground level at 90 cm. The length and breadth of benches were 3×1.2 m that the angle from the center of the bench down at a 2 per cent slope on both sides. Two bags placed on each bench at 60 cm apart from each other and two rows of holes made on top of the each bag at 30 cm apart from each other in alternate manner which accommodated 20 plants per bag. Ten micro tubes per bag inserted between two plants in equal distance with 8 liters per hour discharging capacity.

Verti-Gro system :

The Verti-Gro system employed consisting of vanilla round shaped pots that each having 2.8 litter capacity were placed on above of each other with help of a metal pole to form a cylinder shaped column. The 20 cm PVC cut-pipe sleeves placed between every tow pots to keep pots vertically apart of each other and the first pot from the bottom placed at 45 cm elevation from surface of the ground which gave a column with height of 162 cm. The distance between row and columns was 100 cm and 70 cm, respectively. Each column consist four pots and each pot accommodated four plants with sixteen plants per column. Each pot supplied with nutrient solution through micro tubes with 8 liters per hour discharging capacity from above lateral lines.

One day prior to transplanting, all systems filled with media (coir pith 60%+40% perlite, v/v) and irrigated for one hour to thoroughly moisten the media. Healthy plug of the cultivar Strawberry Festival, procured from ZOPAR Exports nursery Bangalore, were planted in growing systems. The nutrient solution supplied through an automated drip irrigation system. The timer adjusted during day time for 15 minutes each at three hours to supply nutrient solution, from a 400 litres capacity plastic tank placed under shade house outside of greenhouse and the systems ensured 10 per cent drainage. Photosynthetic rate (A; $\mu\text{mol}/\text{m}^2/\text{s}$) and light incident on leaf

surface (Qleaf; $\mu\text{mol}/\text{m}^2/\text{s}$) were also recorded during peak fruiting stage of crop *i.e.* 120 days after transplanting on selected cloudless days at 09:30 to 10:30 am. Complite Randomized Design, design was applied with three treatments each replicated four times. Three plants per replication randomly selected for taking the measurements. The data were statistically analysed by analysis of variance (ANOVA). The treatment means were then separated with the Duncan's multiple range test ($P=0.05$).

RESULTS AND DISCUSSION

Highest number of leaves (41.66) was recorded in Open-trough system, followed by Lay-Flat-Bag system (37.16) and lowest (35.85) in Verti-Gro system. As well as longest petiole (13.60 cm) and larger crown diameter (33.75 mm) was recorded in Open-trough system as compared to Lay-Flat-Bag (30.50 mm) and Verti-Gro (28.18 mm) systems. These results might be attributed to larger substrate volume of Open-trough as compared to Lay-Flat-Bag system. The shading effect of upper tier in Verti-Gro system on lower section reduced the photosynthetic rate and hence plant growth. Similar results were reported by Cantliffe *et al.* (2007) that larger volume of bags (18 L) as compared to polygal troughs (12 L) enhanced the vegetative growth of strawberry plants. According to Al-Raisy *et al.* (2010), in strawberry cv. 'Camarosa' the number of leaves decreased with increase in column size in Verti-Gro system due to reduced light intensity in lower sections.

Maximum leaf area (2478.66 cm^2) was recorded in Open-trough system followed by Lay-Flat-Bag system (2199.82 cm^2) and minimum (1719.24 cm^2) in Verti-Gro system. These findings might be due to the highest number of leaves produced in Open-trough system because of larger growing medium. As reported by Cantliffe *et al.* (2007), the larger volume of the polyethylene bags (18 L) as compared to polygal troughs (12 L) enhanced the vegetative growth of strawberry plants. The reduction in Lay-Flat-Bag might be due to excessive bed temperature due to colour of polyethylene (black). As reported by Lim (1985), the black polythene had 10°C higher temperature

Table 1 : Biometric characters of strawberry cv. STRAWBERRY FESTIVAL grown in passively ventilated greenhouse as influenced by soilless culture systems

Systems	Shoot fresh weight (g)	Root fresh weight (g)	Shoot dry weight (g)	Root dry weight (g)	Crown diameter(mm)	Length of petiole (cm)	No. of leaves/ plant	Leaf area (cm^2)
Open trough	60.79 ^a	16.50 ^a	21.10 ^a	5.74 ^a	33.75 ^a	13.60 ^a	41.66 ^a	2478.66 ^a
Lay-Flat-Bag	56.35 ^b	15.18 ^b	18.02 ^b	4.51 ^b	30.50 ^b	11.91 ^b	37.16 ^{ab}	2199.82 ^b
Verti-Gro	50.70 ^c	13.81 ^c	15.40 ^c	3.58 ^c	28.18 ^b	12.52 ^b	35.85 ^b	1719.24 ^c
F -test	*	*	*	*	*	*	*	*
S.E. \pm	0.83	0.26	0.28	0.18	0.86	0.44	1.00	37.04
C.D. @ 5%	2.48	0.78	0.85	0.55	2.58	1.31	3.01	111.13
C.V. %	5.35	6.23	5.69	14.40	10.09	12.70	9.25	5.65

Note : * Indicate significance of value at $P=0.05$, Figures with no or similar letters are non-significant (C.D. @ 5%)

than white one and this factor reduced the vegetative growth of muskmelon. Record of less vegetative parameters in Verti-Gro system maybe contributed to production of less leaf area. As observed by Jagadeesh (2001), the higher number of leaves (63.73) directly contributed in production of higher leaf area (3541.69 cm²) in strawberry cv. SUJATHA.

The plants grown in Open-trough system produced higher shoot fresh weight (60.97 g) followed by Lay-Flat-Bag system (56.35 g) and was significant over than Verti-Gro system (50.70 g). Similarly highest root fresh weight (16.50g) was recorded in Open-trough system followed by Lay-Flat-Bag system (15.18 g) and lowest (13.81 g) in Verti-Gro system. These results might be due to larger substrate volume of Open-trough system as compared to Lay-Flat-Bag system and higher photosynthetic rate as compared to Verti-Gro system. The report of Cantliffe *et al.* (2007) revealed that larger container volume of polyethylene bags (18 L) increased the vegetative growth of strawberry as compared to smaller container volume of polygal trough (12 L). Lower light penetration to the canopy of plants in lower tier consequently resulted in reduction of plant fresh weight in Verti-Gro system. Similar observations were reported by Al-Raisy *et al.* (2010) that in cv. CAMAROSA highest shoot fresh weight (173.96 g) was produced in column made of 6 pots as compared to 7 pots per column (100.00g) and 8 pots per column (68.23 g), these results was attributed to higher penetration of light to the plants canopy in tower of 6 pots per column in comparison with column of 7 and 8 pots.

Higher shoot dry weight (21.10 g) was produced in Open-trough system followed by Lay-Flat-Bag system (18.02 g) which was significant over than Verti-Gro system (15.40 g). Similarly highest root dry weight (5.74 g) was observed in Open-trough system followed by Lay-Flat-Bag system (4.51 g) and lowest (3.58 g) in Verti-Gro system. These findings might be due to highest shoot and root fresh weight recorded in Open-trough which might contributed in its dry weight. Ercisli *et al.* (2005) reported that higher root fresh weight (25.90 g) was produced higher root dry weight (8.28 g) as compared to lower root fresh weight (11.46 g) produced lower root dry weight (5.51 g) in cv. FERN. Similar observations were reported

by Al-Raisy *et al.* (2010) in cv. CAMAROSA with respect to shoot fresh and dry weights.

Plants grown in Lay-Flat-Bag system took minimum number of days (43) to flower followed by Open-trough (48 days) and it was maximum (59 days) in Verti-Gro system. These results might be due to maximum exposure of plants grown in Lay-Flat-Bag system to light which might trigger floral induction. Ceulemans *et al.* (1986) reported that, when additional light from high-intensity discharge mercury lamps with an intensity of (300 µmol/m²/s) was provided, a gain in earliness of 10 to 15 days of fruit production was achieved in strawberry cv. PRIMELLA. In Open-trough 10 cm height of side walls shaded the lower parts of plant resulted in initial increase of vegetative growth and delayed flower induction. In Verti-Gro system the effect of shading of upper tier on lower plants delayed the transition of vegetative to reproductive growth. Cited by Villiers (2008) that, low light intensity delayed reproductive growth in strawberry (Awang and Atherton, 1995). Albaho *et al.* (2008) reported that the strawberry flower initiation was earlier in closed insulated palate system (16 days ATP) as compared to nutrient film technique (NFT) (28 days ATP). This result was attributed to shading affect of NFT system (15 cm deep) on crown portion of plants.

Highest number of flowers (37.00) was recorded in Open-trough followed by Lay-Flat-Bag (32.58) and lowest (24.70) in Verti-Gro system. Higher number of fruits (22.66) was produced in Open-trough system followed by Lay-Flat-Bag system (18.66) and lowest (15.00) in Verti-Gro system. Similarly, highest fruit weight (281.83 g) was produced in Open-trough system followed by Lay-Flat-Bag system (209.92 g) and significantly lower (145.41 g) in Verti-Gro system. The results obtained might be due to larger container size of Open-trough as compared to Lay-Flat-Bag system and higher photosynthetic rate as compared to Verti-Gro system. Cantliffe *et al.* (2007) reported that, larger container volume of polyethylene bags (18 L) increased the reproductive growth of strawberry plants as compared to smaller container volume of polygal troughs (12 L). Chabot (1978) reported that, wild strawberry (*Fragaria vesca* L.) in high light intensity (300 µmol/m²/s) produced

Table 2 : Flower initiation, yield and fruit quality parameters of Strawberry cv. STRAWBERRY FESTIVAL grown in passively ventilated greenhouse as influenced by soilless culture systems

Systems	Days taken for flowering (days)	Total no. of flowers/plant	Total fruit weight / plant (g)	Total no. of fruits/ plant	Total marketable fruits/ plant (%)	TSS %B	Acidity (%)
Open trough	48.00 ^b	37.00 ^a	281.83 ^a	22.66 ^a	78.33 ^a	10.46 ^a	0.83 ^b
Lay-Flat-Bag	42.66 ^b	32.58 ^b	209.92 ^b	18.66 ^b	61.91 ^b	10.61 ^a	0.80 ^b
Verti-Gro	59.00 ^a	24.70 ^c	144.41 ^c	15.00 ^c	60.93 ^b	9.68 ^b	0.92 ^a
F-test	*	*	*	*	*	*	*
S.E.±	0.61	1.26	11.79	0.57	1.54	0.13	0.02
C.D. @ 5%	1.84	3.80	35.38	1.73	4.62	0.41	0.06
C.V. %	4.45	14.41	20.05	11.12	8.30	4.82	8.44

Note: * Indicate significance of value at P=0.5, Figures with no or similar letters are non-significant (C.D. @ 5%)

significantly more flowers per plant than at lower light intensity (22 or 150 $\mu\text{mol}/\text{m}^2/\text{s}$). The larger number of flowers could also help in larger fruit set. As observed by Omari (2008), in cv. 'Sujatha' more number of flowers (25.49) set more number of fruits (21.89). Al-Raisy *et al.* (2010) reported that, in strawberry cv. CAMAROSA fruit weight decreased from (132.24 g) to (118.32 g) and (107.00g) when the column size of Verti-Gro system increased from 6 pots per column to 7 and 8 pots per column, respectively. A-shape system produced slightly more (20.09) fruit per plant as compared to (18.88) in Verti-Gro system (Villiers, 2008).

Significantly higher marketable fruits (78.33 %) were produced in Open-trough as compared to Lay-Flat-Bag (61.91%) and Verti-Gro (60.93%) systems, but results in Lay-Flat-Bag and Verti-Gro systems were statistically on par with each other. This difference might be attributed to higher bed volume of Open-trough system as compared to Lay-Flat-Bag system which might subsequently increased the water and nutrient absorption by plants. Awad *et al.* (2010) reported that, due to adequate level of nitrogen absorbed by strawberry plants, the vegetative growth increased hence the photosynthesis rate which consequently resulted in enhanced marketable fruits. Apart from low photosynthetic rate which was recorded in Verti-Gro system, other factor for reduction in marketable fruit can be attributed to low light level which causes stamen sterility and poor pollen quality hence reduction in fertilization rate that might contribute to malformed fruit production (Smeets, 1980). Similar findings reported by Villiers (2008) that, malformation of strawberry cv. SWEET CHARLIE increased by increase in shading percentage from 0 to 50.

In strawberry the total soluble solids is one of the reliable indicators of strawberry eating quality and photosynthesis net assimilation rate is also one of the important factors in its production. Higher TSS (10.61 °B) was recorded in fruits produced in Lay-Flat-Bag system which was on par with Open-trough system (10.46 °B) and was significant over Verti-Gro system (9.68 °B). This difference might be attributed to higher photosynthetic rate that was recorded in first two systems as compared to Verti-Gro system. According to Miura *et al.* (1993), shaded strawberry fruits had lower levels of sugars as compared to unshaded fruits. Similar results were reported by Villiers (2008) that highest TSS (8.70 °B) was observed in strawberry cv. CHANDLER fruits produced in A-shape system as compared to Verti-Gro system (8.28 °B) due to higher light intensity recorded in A-shape system. Vasilakakis *et al.* (2005) reported that, there was tendency to varied increase (5-8 %) of berry TSS% along with the increase of light intensity.

Significantly lower titratable acidity (0.80 %) was recorded from fruits produced in Lay-Flat-Bag system which was on par with Open-trough system (0.83 %) and highest (0.92 %) in Verti-Gro system. This result might be attributed to higher fruit load of plants grown in Open-trough and Lay-Flat-Bag

systems as compared to Verti-Gro system. Vasilakakis *et al.* (2005) reported that, titratable acidity of strawberry fruits was varied between (0.8 %) and (1.8 %) as affected negatively by the plant fruit load.

Highest photosynthetic rate (4.08 $\mu\text{mol}/\text{m}^2/\text{s}$) was recorded in Open-trough system which was on par with Lay-Flat-Bag system (3.32 $\mu\text{mol}/\text{m}^2/\text{s}$) and lowest (1.50 $\mu\text{mol}/\text{m}^2/\text{s}$) in Verti-Gro system (Fig. 1). These results might be attributed to quantitatively equal light incidence on leaf surface was recorded in Open-trough and Lay-Flat-Bag systems and lowest in Verti-Gro system. This low light intensity was the result of shading affect of the upper tier on lower section of the Verti-Gro system (Durner, 1999) as a result the photosynthetic rate reduced. Similar observations were reported by Villiers (2008) who compared A-shape and vertical growing systems on yield and fruit quality of cv. 'Chandler' and Al-Raisy *et al.* (2010) compared the size of column in vertical growing system on growth and yield of cv. 'Camarosa.' They observed that low light intensity in vertical system or big size of column caused consequently lower photosynthesis net assimilation rate.

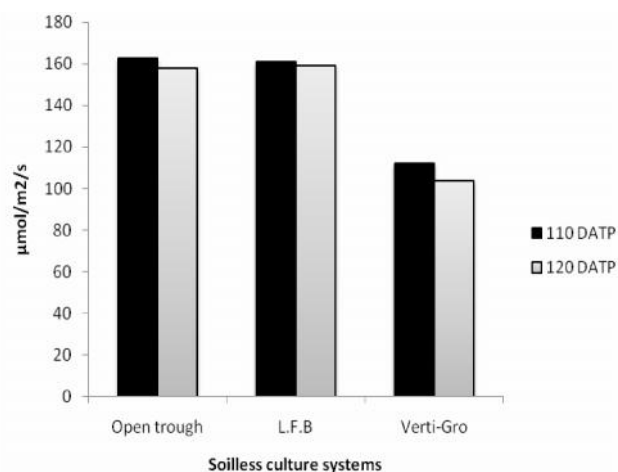


Fig. 1: Light incidence on leaf surface of strowberry cv. STRAWBERRY FESTIVAL as influenced by soilless culture systems

Highest light incidence on leaf surface (159.33 $\mu\text{mol}/\text{m}^2/\text{s}$) was recorded in Lay-Flat-Bag system which was statistically on par with Open-trough system (158.00 $\mu\text{mol}/\text{m}^2/\text{s}$), but lowest (103.66 $\mu\text{mol}/\text{m}^2/\text{s}$) was recorded in Verti-Gro system (Fig. 2). It is clear that light intensity and distribution are limited factors with the use of Verti-Gro system (Villiers, 2008) as vertical growing system caused lower light than optimum in the lower tier (Takeda, 2000). This result might be attributed to the uniform planting density in Open-trough and Lay-Flat-Bag systems and their uniform elevation inside the greenhouse due to which equal light intensity on leaf surface recorded. The shading effect of upper tier in Verti-Gro system reduced the overall light incidence on leaf

surface in lower section. As reported by Paraskevopoulou *et al.* (2005), higher light intensity was recorded on strawberry plants grown in pots placed on flat surface as compared to plants grown in vertical grow bags.

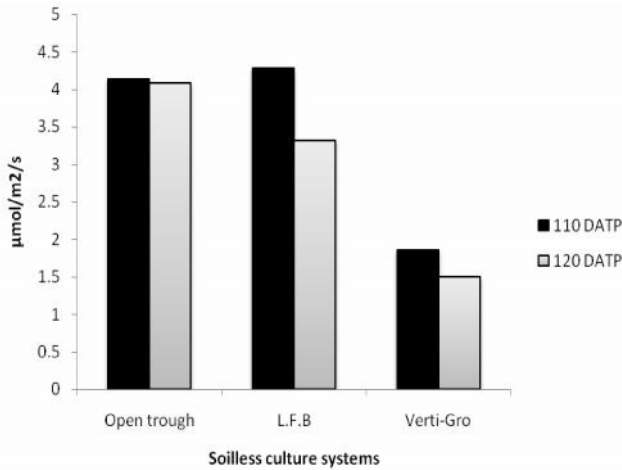


Fig. 2: Photosynthetic rate of strawberry cv. STRAWBERRY FESTIVAL as influenced by soilless culture systems

The best results obtained from Open-trough system which contained more substrates as compared to Lay-Flat-Bag system and higher light intensity received by plants grown in this system. But for maximum utilization of growing site, the Verti-Gro system found to be the best option for commercial production as well as home gardening. But limited light intensity and consequently lowest photosynthetic rate in lower tier caused markedly decrease in growth, yield and fruit quality of strawberry.

The environmental condition of passively ventilated greenhouse is not suitable for cv. STRAWBERRY FESTIVAL performances under Bangalore conditions. It was due partly to soaring temperature recorded during crop growth and poor pollination of flowers; therefore soilless strawberry production may be tried in open field or under shade net.

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