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EFFECT OF PLANTING DENSITY AND GROWING MEDIA ON GROWTH AND YIELD OF STRAWBERRY

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ABSTRACT:- Strawberry (*Fragaria ananasa*), belonging to Rosaceae family, is a rich source of vitamins and minerals with delicate flavors. It is perishable crop which is exceedingly in demand for its taste, profitability, high yield and good quality. To make the plant growth successful in the container, the requirement of special media is very important step because plant growth is largely depended on the physiochemical properties of the growing media used. Winter strawberry production in a greenhouse using high plant densities and various media may be a viable alternative to open-field production system. Planting density can be increased thrice by using different production systems. Studies were conducted to see the impact of different planting densities and media on growth and yield of strawberry. The treatments were T_1 = Control, with normal planting distance of 30 cm x 60 cm and growing media silt, sand and farm yard manure (FYM); T_2 = 15 cm x 30 cm and silt, sand and FYM; T_3 = 30 cm x 60 cm and coir; T_4 = 15 cm x 30 cm and coir; T_5 = 30 cm x 60 cm and peat moss; T_6 = 15 cm x 30 cm and peat moss. Results showed that plants grown at low planting distance on all growth media showed more pronounced results as compared to high planting distance. Plants grown in peat moss at both planting densities moderately increased the plant height, canopy size, leaf area, number of fruits, fruit size, fruit weight and titratable acidity. A significant increase in fresh and dry weight of leaves, number of leaves, fruit yield in term of fruit number, fruit size and fruit weight, and fruit quality with high ascorbic acid contents were observed. On the other hand, plants grown in silt, sand and FYM (1 : 1 : 1) at both planting densities showed significant increment in vegetative growth resulting in early flowering with more flowers per plant, better fruit setting and fruit set percentage, greater fruit size and weight but fruit number per plant was reduced which lowered the overall yield. While the fruit produced had more Total Soluble Solid (TSS). Plants grown in coir based growing media showed significant increase only in titratable acidity and ascorbic acid content of fruit.

Key Words: Fragaria ananassa; Growing Media; Planting Density; Total Soluble Solids; Ascorbic Acid; Titratable Acidity; Farm Yard Manure; Coir, Peat Moss; Pakistan.

INTRODUCTION

Strawberry (*Fragaria ananassa*) belongs to Rosaceae family of the genus *Fragaria* (Hancock, 1999). It is a modern cultivated variety which is a hybrid of *F. virginiana* (meadow strawberry) and *F. chiloensis* (Chilean

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strawberry) (Hancock, 1999; Bowling, 2000). It is a rich source of vitamins and minerals with delicate flavors (Sharma, 2002). It also contains a higher percentage of phenolics and flavonoids (Hakkinen and Torronen, 2000). Pakistan is producing a limited quantity of strawberries. The estimated per acre income of strawberry is about Rs. 100,000 per season (Khushk and Memon, 2005). It is desirable to enhance the yield of horticultural crops not only quantitatively but also qualitatively with ever limiting resource of cultivated lands.

Planting density plays an important role in achieving high productivity per unit area. High planting density along with low level of N fertilization on flat uncovered beds resulted in highest yield, largest berries, and the best quality fruit as compared to polyethylene covered raised beds (Petersen, 1998). In strawberry, marketable yields were higher at narrower spacing than wider spacing (Legard et al., 2000). Winter strawberry production in a greenhouse using high plant densities and soilless substrates may be a viable alternative to open-field with methyl bromide fumigation production system (Paranjpe et al., 2003). Early and total marketable yields, crown diameter, and leaf number of strawberry plants grown at 35 cm within-row plant spacing were significantly greater than those of grown at 17.5 cm row spacing. Total and early marketable yield increased linearly as plant density increased (Paranjpe et al., 2008). Growth and yield per plant increased by increasing plant spacing from 20 to 30 cm and also resulted in a greater leaf area and leaf area index, but the highest harvest index and yield per square metre were obtained at the closest spacing (De-Camacaro, 2004). Cold stored strawberry plants gave 127% higher marketable yield in denser planting (6.6 plant m^{-2}) than for sparser planting (3.3 plant m^{-2}) in the first growing season while in the second growing season, 32% higher yield was observed in double density planting than in sparser planting (Laugale et al., 2012). Planting density also greatly influence production and fruit quality of strawberry plants that are grown from cuttings (Jansen, 1997). Improper selection of plant population density and poor management of soil fertility limit the productivity and acreage of strawberry.

Soilless media are also relatively light weight, readily available and more uniform and more suitable for containerization than mineral soils (Yuan et al., 1996). As a result, there is a worldwide expansion of the use of soilless growing media during the last decades (Raviv et al., 2002). In strawberry culture, severe production losses are caused by soil-borne diseases. Therefore, there is a trend towards using soilless media to avoid diseases (Jansen, 1997). Most growing media for strawberries are peat moss, rockwool, coir, perlite or some other mixtures. The number of leaves, runners and crown diameter in Camarosa, Gaviota and Selva cultivars of strawberry were higher in media of peat and coco peat as compared to media with sand and perlite 100 % (Tehranifar et al., 2007). Slag and peat media improved aeration condition forming greater root system, promoted shoot nutrition uptake, strengthened activities of capturing light and increased yield

(Du et al., 2007). Strawberry grown in coir showed better results as compared to that grown in perlite (Lopez-Medina et al., 2004; Maher et al., 2008). Rockwool is the most significant growing media for strawberry. It helps in achieving highest number of leaves and greater diameter of crown. It also affects fresh weight of the plant and dry matter content of root system (Bartczak et al., 2007). Composting and the use of compost products in horticulture and agriculture have been researched widely (Ismail et al., 2011). Compost as a soil supplement enhanced strawberry plant growth and fruit quality (Wang and Lin, 2003). Growth was more vigorous and yield was higher on rockwool granules than on slabs. CO_2 enrichment increased total yield by 50% on rockwool slabs and 30% on granules, compared to controls. Total yield/plant increased by 50-70% under CO_2 enrichment. Yield per peat bag increased with increasing planting density under CO_2 enriched conditions. Under control conditions, increasing plant density had little effect on yield. Soluble solid content and titratable acidity of fruits were also increased by CO_2 enrichment (Itani et al., 1999).

Therefore, the present studies were conducted to investigate the effect of different planting densities and growing media on vegetative and reproductive growth and improvement of fruit quality, of strawberry.

MATERIALS AND METHOD

Present studies were conducted at research area of Horticulture Department, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan during 2011-2012. Strawberry runners were obtained from Swat and kept in cool chamber at 4°C for 8-15 days to fulfill the chilling requirement of the crop. Plants were grown in white plastic bags 75cm x 45cm in size. To check the impact of different planting densities and media on growth and yield of strawberry, different treatments were used (Table 1). Each treatment consisted of three replications with ten plants per replication. The experiment was designed according to the Randomized Complete Block Design (RCBD). Data were taken for vegetative growth characteristics including plant height, leaf area, crown diameter, canopy spread, number of leaves, fresh and dry weight of plant and leaves at final growth stage while reproductive traits included number of trusses, flowers and fruits, fruit set percentage, fruit weight and fruit size; and quality parameters included total soluble solids, titratable acidity and ascorbic acid contents. The data were analyzed using MSTAT-C and means were compared by using Least Significant Difference test (LSD) at 5% probability level (Steel et al., 1997).

Table 1. Layout of experiment

Treatments	Planting density (cm)	Growth media
T_1	30 x 60	Silt, sand and FYM (1:1:1)
T_2	15 x 30	Silt, sand and FYM (1:1:1)
T_3	30 x 60	Coir
T_4	15 x 30	Coir
T_5	30 x 60	Peat moss
T_6	15 x 30	Peat moss

RESULTS AND DISCUSSION

Statistical analysis of data regarding plant height showed significant effect of planting density and media (Table 2). Among all treatments, control (T_1) showed maximum plant height (20.22 cm) followed by T_2 (19.83 cm), T_6 (16.45 cm), T_5 (15.44 cm), T_4 (13.38 cm) and T_3 (12.78 cm). Our results agreed with researchers who found that farm yard manure along with different planting densities had a significant effect on growth, fruit yield and quality of strawberries (Iqbal et al., 2009; Ogendo et al., 2008). An increase in crown diameter means more vegetative growth i.e., an increase in number of lateral branches, flowering trusses, runner and leaves. Maximum crown diameter (1.40 cm) was obtained in plants grown in silt, sand and FYM (1:1:1) at 15cm x 30cm (T_2) followed by $T_5 > T_6 > T_3 > T_1$. Minimum crown diameter (1.06 cm) was produced by coir at 15cm x 30cm (T_4). Peat moss enhanced crown diameter in strawberry plants at both planting densities and same results were found by Tehranifar et al. (2007).

Maximum number of strawberry leaves (6.78) was observed in peat moss at 30cmx60cm (T_5) while minimum (4.00) were observed in coir at 15cmx30cm (T_4). The maximum number of leaves per plant was recorded in T_5 followed by $T_1 > T_6 > T_3 > T_2 > T_4$. Peat moss at low planting density increased number of leaves per plant by reducing interplant competition for plant nutrients (Galletta and Himelrick, 1990). Similar results were found by Tehranifar et al. (2007) and Paranjpe et al. (2008). The significance level for planting density and media showed that maximum leaf area (63.85 cm^2 and 60.35 cm^2) was observed in silt, sand and FYM (1:1:1) at 15cm x 30cm (T_2) and at 30cm x 60cm (T_1), respectively followed by $T_6 > T_5 > T_3 > T_4$. More leaf area in FYM based media at both high and low density might be due to more organic matter and other nutrients availability to the plants through manures . The same results were found by Iqbal et al. (2009) and Mahadeen (2009) in strawberry plants and by Akparobi (2009) in *Amaranthus cruentus*. The results obtained in peat moss were supported by the Awang et al. (2009) who found that coco peat in mixture form enhanced the leaf area in *Celosia cristata*. On the other hand, coir appeared less effective in increasing leaf area at both planting distances. Our results agreed with those of De-Camacaro (2004).

The statistical data on fresh weight of plants (FWP) showed that maximum fresh weight of strawberry plants (22.21 g) was produced by sand, silt and FYM at 15cm x 30cm (T_2) while minimum (5.80 g) was observed in coir at 15cm x 30cm (T_4). The maximum fresh weight of plant was recorded from T_2 followed by $T_1 > T_6 > T_5 > T_3 > T_4$. Highly significant ($P<0.05$) increase in dry weight of plants (DWP) was observed in the plants grown in silt, sand and FYM (1:1:1) at 15cm x 30cm (12.71 g) as compared to other treatments. The maximum dry weight of plant was observed in T_2 followed by $T_1 > T_5 > T_6 > T_3 > T_4$. Maximum FWP in FYM based media at high density might be due to its positive effect on vegetative parameters; thus increasing growth and development of strawberry plants. Our findings are in accordance with

Table 2. Effect of planting density and growing media on vegetative growth parameters of strawberry

Treatment	Plant height (cm)	No. of leaves	Leaf area (cm^2)	Crown diameter (cm)	Canopy spread (cm)	Fresh weight of plants (g)	Dry weight of plants (g)
T_1	20.22 ± 2.30 [a]	6.33 ± 0.19 [a]	60.35 ± 4.42 [ab]	1.19 ± 0.09 [cd]	24.33 ± 1.92 [a]	17.77 ± 3.89 [ab]	09.54 ± 1.56 [b]
T_2	19.83 ± 2.98 [a]	5.55 ± 0.55 [ab]	63.85 ± 3.05 [a]	1.40 ± 0.04 [a]	24.89 ± 1.53 [a]	22.21 ± 3.38 [a]	12.71 ± 1.00 [a]
T_3	12.78 ± 0.59 [d]	5.77 ± 0.40 [a]	28.01 ± 2.42 [c]	1.24 ± 0.04 [bc]	16.28 ± 0.20 [b]	10.27 ± 0.33 [bc]	03.40 ± 0.20 [cd]
T_4	13.38 ± 2.77 [cd]	4.00 ± 0.19 [b]	18.59 ± 1.36 [d]	1.06 ± 0.02 [d]	14.83 ± 1.05 [b]	05.80 ± 1.48 [c]	02.19 ± 0.48 [d]
T_5	15.44 ± 1.35 [bc]	6.78 ± 0.49 [a]	52.28 ± 1.45 [b]	1.37 ± 0.07 [ab]	23.00 ± 1.00 [a]	12.20 ± 1.13 [bc]	05.33 ± 0.30 [c]
T_6	16.45 ± 1.24 [b]	6.00 ± 0.96 [a]	57.38 ± 2.35 [ab]	1.27 ± 0.01 [abc]	22.61 ± 1.19 [a]	13.58 ± 1.81 [b]	04.94 ± 0.53 [c]

Means followed by same letters do not differ significantly at 5% level

Table 3. Effect of planting density and growing media on reproductive growth parameters of strawberry

Treatment	No. of days to open 1st flower	No. of trusses	No. of flowers per plant	Fruit set (%)	No. of fruits	Fruit weight (g)	Fruit size (cm)
T_1	117.7 ± 1.20 [a]	2.00 ± 0.00 [ab]	22.44 ± 3.94 [ab]	54.00 ± 12.44 [ab]	3.96 ± 0.58 [a]	4.05 ± 0.35 [ab]	2.64 ± 0.19 [a]
T_2	114.3 ± 0.67 [ab]	1.98 ± 0.19 [ab]	25.32 ± 2.27 [a]	57.67 ± 2.90 [a]	5.28 ± 0.33 [a]	2.68 ± 0.36 [c]	2.49 ± 0.10 [ab]
T_3	110.3 ± 2.33 [b]	2.68 ± 0.00 [a]	16.22 ± 1.21 [ab]	45.33 ± 3.18 [ab]	4.62 ± 0.33 [a]	2.54 ± 0.38 [c]	2.25 ± 0.09 [bc]
T_4	108.7 ± 5.55 [b]	1.32 ± 0.19 [b]	14.44 ± 3.61 [b]	41.67 ± 9.94 [b]	5.28 ± 0.33 [a]	2.83 ± 0.37 [bc]	2.07 ± 0.08 [c]
T_5	113.3 ± 2.40 [ab]	2.44 ± 0.11 [a]	15.32 ± 1.79 [b]	43.67 ± 2.33 [ab]	5.28 ± 0.33 [a]	3.48 ± 0.34 [b]	2.37 ± 0.11 [abc]
T_6	108.0 ± 4.16 [b]	2.88 ± 0.22 [a]	6.60 ± 0.11 [b]	45.33 ± 4.91 [ab]	5.94 ± 0.57 [a]	4.17 ± 0.38 [a]	2.60 ± 0.13 [a]

Means followed by same letters do not differ significantly at 5% level

the work of many researchers (Ogendo et al., 2008; Iqbal et al., 2009 and Kuepper, 2003). Peat moss also showed favorable results for FWP and DWP at both densities which might be due to its good physical, chemical and biological characteristics that improved aeration for forming greater root system, promoted shoot nutrition uptake, and strengthened activities of capturing light and increased yield of strawberry plants (Du et al., 2007; Ercisli et al., 2005 and Tehranifar et al., 2007). Coir medium at both densities was not effective in enhancing DWP. Similar results were found by Treder (2008) in lily plants. Results showed that silt, sand and FYM (1:1:1) at 15cm x 30cm produced maximum canopy spread (24.89 cm) which might be due to the fact that it was a rich source of potash and phosphorous for the better growth of plants (Kuepper, 2003) and it also significantly increased number of leaves and the same results were found by Iqbal et al. (2009). The maximum canopy spread was T_2 followed by $T_1 > T_5 > T_6 > T_3 > T_4$. Peat moss have good effect on vegetative growth parameters like canopy spread in strawberry plants (Tehranifar et al., 2007). Higher canopy diameter at lower planting density in peat moss and coir might be due to reduced interplant competition for resources (Galletta and Himelrick, 1990).

It was found that peat moss at 15cm x 30cm (T_6) induced flowering earlier (108.0 days) by reducing the days to open the first flower while maximum number of days (117) was observed in control followed by $T_2 > T_5 > T_3 > T_4 > T_6$ (Table 3). Maximum days for flower opening in FYM based media at low density might be due to more availability of nutrition which prolonged the vegetative growth period and delayed reproduction. Our results are in agreement with those observed by Ahmed et al. (2004) in dahlia flower opening. Maximum number of trusses (2.88) was found in peat moss at 15cm x 30cm (T_6) while minimum (1.32) was observed in coir at 15cm x 30cm (T_4). Maximum number of flowers per plant (25.32) was recorded in silt, sand and FYM (1:1:1) with 15cm x 30cm (T_2) while minimum (14.94) was observed in coir at 15cm x 30cm (T_4). Maximum fruit set percentage (57.67%) was found in silt, sand and FYM (1:1:1) at 15cm x 30cm (T_2) while minimum (41.67 %) was found in coir at 15cm x 30cm (T_4). T_2 was followed by $T_1 > T_3 > T_6 > T_5 > T_4$. The reduction in flower number and fruit set percentage at 30cm x 60cm in FYM and peat moss might be due to high light intensity which was absorbed under low planting density regime and reduced flowering of strawberry (Ferree, 1988).

Results showed that maximum number of fruits (5.94) were observed in peat moss at 15cm x 30cm (T_6) while minimum (3.98) was in control (T_1). T_6 was followed by $T_2 > T_4 > T_5 > T_3 > T_1$. High planting density showed higher number of fruits in peat moss, coir and FYM based growing media. The increase in yield with the denser plantings might be due to increase in fruit number. Our results are also similar to other researchers (Sarooshi and Cresswell, 1994; Legard et al., 2000; Duralija et al., 2006; Ogendo et al., 2008 and Paranjpe et al., 2008). Results revealed that maximum fruit size (2.64 cm) was produced in control plants (T_1) while minimum (2.07 cm)

was produced in coir at 15cm x 30cm (T_4). T_1 was followed by $T_6 > T_2 > T_5 > T_3 > T_4$. Maximum fruit size was obtained in FYM based growing media at low planting density which might be due to more available phosphorous nutrient, high organic matter and total organic nitrogen percentage that enhanced the fruit size in strawberry by the formation of carbohydrates. Our findings agree with those of Maegowa and Minegishi (1991); Iqbal et al. (2009) and Isutsa et al. (2011). Minimum fruit size in coir at high densities might be due to N immobilization property of the coir media and more competition among plants for nutrients and moisture that resulted in reduction in fruit size (Handreck, 1993).

Results demonstrated that maximum fruit weight (4.17 g) was produced in peat moss at 15cm x 30cm (T_6) while minimum (2.54 g) was produced in coir at 30cm x 60cm (T_3). T_6 was followed by $T_1 > T_5 > T_4 > T_2 > T_3$. These results agreed with those obtained by Cantliffe et al. (2007); Ogendo et al. (2008) and Ahmad (2009). The data for TSS depicted that maximum TSS (15.66 ^{0}Brix) was found in silt, sand and FYM (1:1:1) at 15cm x 30cm (T_2) while minimum (7.63 ^{0}Brix) was produced in peat moss at 30x60cm (T_5) (Table 4). The results in this regard were in the order of T_2 followed by $T_6 > T_1$, $T_3 > T_4 > T_5$. Our findings agree with the work of Mahadeen (2009) and Tuzel et al. (2003) on strawberry and tomatoes respectively, who reported that there was no effect of organic or inorganic media on TSS contents of these crops. Strawberries are very good source of ascorbic acid (vitamin C) (Anonymous, 1989) and contains higher amount of vitamin C than oranges (Ayub et al., 2010) Results demonstrated that maximum ascorbic acid (89.09 mg 100ml^{-1} juice) was observed in peat moss at 15cm x 30cm (T_6) while minimum (86.24 mg 100ml^{-1} juice) was recorded in control (T_1). The order of impact was T_6 followed by $T_4 > T_2 > T_5 > T_3 > T_1$. The sustainable production system produced 20 % more ascorbic acid in strawberries as compared to conventional growing system that might be due to improvement of soil structure by the addition of organic media (Asami et al., 2003).

Table 4. Fruit quality parameters of strawberry as affected by planting density and growing media

Treatment	Total soluble solids (^{0}Brix)	Titratable acidity (%)	Ascorbic acid (mg 100^{-1} ml juice)
T_1	8.33 ± 0.88 ^{b}	0.62 ± 0.15	86.24 ± 2.01 ^{b}
T_2	15.66 ± 3.48 ^{a}	0.64 ± 0.18	87.13 ± 0.69 ^{ab}
T_3	8.33 ± 1.20 ^{b}	0.64 ± 0.00	87.00 ± 1.11 ^{ab}
T_4	8.30 ± 1.89 ^{b}	1.00 ± 0.13	88.72 ± 0.24 ^{ab}
T_5	7.63 ± 0.58 ^{b}	0.78 ± 0.14	88.11 ± 0.44 ^{ab}
T_6	9.36 ± 1.40 ^{b}	0.68 ± 0.11	89.09 ± 0.53 ^{a}

Means followed by same letters do not differ significantly at 5% level

The sugars and acids are the most important taste attributes in strawberries (Wozniak et al., 1997). High titratable acidity means more acidic fruit which is not desired by the consumer. There was no significant effect of planting density and media on titratable acidity of strawberry. Data showed that maximum titratable acidity (1.00%) was produced in coir based growing media at 15cm x 30cm (T_4) while minimum (0.62%) in control (T_1). T_4 was followed by $T_5 > T_6 > T_2$, $T_3 > T_1$. Our results match with those obtained by Ameri et al. (2012).

It is therefore, concluded that strawberry plants responded better on the peat moss based growing medium at both planting densities for their growth and quality features while silt, sand and FYM (1 : 1 : 1) at high planting density proved better for reproductive growth and quality traits. Coir based growing media did not show satisfactory improvement in vegetative and reproductive growth attributes of the strawberry plants.

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