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Variations in Growing Media and Plant Spacing for the Improved Production of Strawberry (*Fragaria ananassa* cv. Chandler)

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Strawberry was considered to be the fruit of temperate areas, but now it can be grown anywhere in the world such as in Pakistan and even in the Philippines. Strawberry is rich in vitamins and minerals – it is an excellent source of vitamins C and K; it likewise provides a good dose of fiber, folic acid, manganese, and potassium. They also contain significant amounts of phytonutrients and flavonoids, which make strawberries bright red. The study was designed to evaluate the effect of organic growth media amendments and plant spacing on the growth and yield of strawberry (*Fragaria ananassa* cultivar Chandler). Four different growth media – soil + peat moss, soil + poultry waste, soil + farm yard manure, and the combination of all these four media additives mixed with soil – were used with different plant-to-plant spacing of 20, 30, and 50 cm to evaluate their effect on the fruit size, total soluble solids (TSS), fruit yield, chlorophyll content, and fruit quality (*i.e.*, fruit color and taste) of strawberry. These treatments were compared with soil only. The effect of soil combined with peat moss was significantly the best among all growth and fruit quality parameters tested. Peat moss amendment showed the highest fruit yield (531.56 g), chlorophyll content (12.53), TSS (8.45), fruit size, and fruit quality (red color with maximum sweet taste) compared with other growing media. The significant effects of all the parameters tested were confirmed through statistical analysis. Meanwhile, the results proved that 20 cm plant-to-plant spacing was the best – in terms of yield – for strawberries when planted in peat moss combined with soil. Hence, the study concludes that the production of strawberries (cultivar Chandler) was improved by utilizing 20 cm plant-to-plant spacing with peat moss amendments.

Key words: growth media, horticultural crop, organic farming, peat moss, plant spacing, strawberry

INTRODUCTION

Strawberry (*Fragaria ananassa*) belongs to Rosaceae family of the genus *Fragaria* (Hancock 1999). Strawberries are unique – with highly desirable taste and flavor – and are excellent source of vitamins, potassium, fiber, and sugars (Sharma 2004). It is marketed in winter and early spring. It is sold for high prices; therefore, it is assumed to be a profitable fruit. Aside from being a table fruit, it can also be used for several purposes such as jam, marmalade, juices, ice cream, and as frozen fruit. Strawberries contain a higher percentage of vitamin C, phenolics, and flavonoids compared with other berry fruits (Häkkinen & Törrönen 2000).

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Pakistan is producing a limited quantity of strawberries. Therefore, it is paramount to enhance the yield of horticultural crops not only quantitatively but also qualitatively with every limiting resource of cultivated land. In Pakistan, the different cultivars of strawberry are mainly cultivated in Charsada, Gujrat, Haripur, Islamabad, Karachi, Lahore, Mansehra, Mardan, and Swat. Specifically, cultivar Chandler is widely cultivated in Islamabad and Pothar region, while the other cultivars – Douglas, Pajaro, and Commander – are only cultivated for research purposes (Khalid *et al*. 2013). The soil pH range for strawberry production is about 4.6–6.5 (Milošević 1997). Since strawberry can easily adapt to its environment and it can be obtained almost in all seasons, it has an expanded culture in the markets and its marketability is high.

Although global demand for organic strawberries remains robust, consumer demand for these products is concentrated in North America and Europe (Willer *et al*. 2009). More than two-thirds of U.S. consumers buy organic products at least occasionally, and 28% buy organic products weekly (Greene *et al*. 2009).Three of the most important reasons consumers purchase organic foods are health benefits (*i.e*., less pesticide residues and greater nutrition), taste, and environmentally friendly farming practices – such as those that promote soil health (Lockie *et al*. 2006). Reganold *et al*. (2010) mentioned that organic strawberry farms produced higher quality fruit, and that their higher quality soils may have greater microbial functional capability and resilience to stress. These findings justify additional investigations aimed at detecting and quantifying such effects and their interactions.

The quality and performance of strawberries greatly depend on the growing media used. Soilless culture of strawberries is increasing in the world. The crucial part in soilless culture of strawberry is the determination of what growing media and which cultivar is economical and reliable. Soilless substrate media have long been used for growing horticultural plants in different forms and sizes of containers under protected environments (Carlile *et al*. 2015). Most growing media for strawberries in soilless culture are peat moss, rockwool, coir, perlite, or some other mixtures. Nowadays, using mixture of peat moss and perlite is one of the mostly used substrate for production of hydroponic strawberries in developing countries. Perlite/peat moss substrate produced the most number of leaves and flowers, number of fruits, and fruit dry weight. Perlite/peat moss is the best growing media used in the production of strawberries in Iran (Jafarnia *et al*. 2010). Peat moss has been one of the most widely used growing medium; however, there have been increasing concerns during its harvest for causing degradation of wetlands and loss of soil organic carbon (Carlile & Coules 2013).

Adak *et al*. (2018) mentioned some of the advantages of soilless production systems over conventional systems, which include higher yield, better pest control management, and more efficient labor use. Among berries, strawberry responds quite well to soilless production systems. Major yield-affecting factors for strawberries in soilless systems may be listed as: growing medium, source and types of plantlets, density of plants, and efficiency of fertigation system. Results showed that growth medium had an effect on yield, numbers of developed leaves, shoot-root dry mass, and number and length of roots. Yield was correlated with these morphological features. Growth medium also had an influence on plant nutrient accumulations *i.e*., shoot accumulation of nitrogen (N) and potassium (K) plus root accumulation of phosphorus (P) and all the micronutrients with the exception of boron (B).

Aside from growing media, the success of strawberry production relies on proper plant spacing. Plant spacing ensures optimum plant growth through adequate utilization of moisture, light, spacing, and nutrients (Zubeldia & Gases 1977). In a study by Paranjpe *et al*. (2008), plant densities were evaluated on growth and fruit yield of 'Sweet Charlie' strawberry (*Fragaria ananassa* Duch.) grown in a passively ventilated greenhouse. Plant densities were derived by varying within-row plant spacings (PS) (17.5 and 35 cm) with between row spacings (RS) (40, 45, 50, 55, 60, and 65 cm). Plants were grown in Polygal1 'Hanging Bed-Pack' troughs filled with pine bark and fertigated with a complete nutrient solution. Generally, plants grown at 17.5 cm PS had smaller crowns and had lower total marketable yields per plant than those grown at 35 cm PS.

According to Reganold *et al*. (2010), the majority of previous organic/conventional studies have focused on either comparing fruit quality or soil quality. Only a few studies have compared both facets, which limited their analyses to selected properties. Currently, no published study has integrated interdisciplinary knowledge and robust methodologies in a systems approach to quantitatively compare a comprehensive range of both fruit quality and yield performance indices using soil amendment treatments. Hence, this study was conducted to evaluate the growth performance and quality of strawberry using different growing media and to optimize the plant spacing for better yield performance.

MATERIALS AND METHODS

The research was conducted at the Department of Horticulture, Bahauddin Zakariya University, Bahadur Sub-Campus, Layyah, Pakistan in the field conditions. Experiment started in the month of Nov 2016 and ended in the last week of Mar 2017. The experiment was conducted for 19 weeks.

The treatments used in the experiment were shown in Table 1.

Table 1. Five types of media used in experiment.

Treatments	Growing Media	pH Range of the Media
T_0	Control (Soil)	7–7.8
T_1	Soil + Peat Moss	5.5–6.5
T_2	Soil + Poultry Waste	6.5–8
T_3	Soil + Farm Yard Manure	7–8
T_4	Soil + Peat Moss + Poultry Waste + FYM	7–8

The research was conducted using the strawberry cultivar 'Chandler,' which was planted on 04 Nov 2016 at the experimental area (field) of the university. The runners of the strawberry plants were taken from Swat, Pakistan – situated in Khaber Pakhtunkha province of Pakistan. Three beds were made for each plot measuring 2.59 x 4.87 m, in which 12 kg of media was mixed in soil before making the beds for each treatment (Table 1).

Growing Media

Different growing media were assessed in this study. As shown in Table 1, T_1 was a mixture of soil and peat moss; T_2 was a mixture of soil and poultry waste; T_3 was a mixture of soil and farm yard manure; while T_4 was a combination of soil, peat moss, poultry waste, and farm yard manure. On the other hand, T_0 served as the negative control as it was made purely of soil *i.e.*, no media amendments were added.

Strawberry Runner Transplantation

Plugs were transplanted into the prepared beds, which contained the soil mixed with different media. Meanwhile, three plant spacing was devaluated – having plant-to-plant distances of 20, 30, and 50cm – in order to optimize the best plant spacing in Thal region. Plastic mulch was laid before sowing to avoid weeds that compete with plant growth and to avoid the fruit from touching the soil and water. Water was applied on a weekly basis and irrigation was installed in winter low tunnels to avoid frost. The entire experiment was arranged in Randomized Complete Block Design (RCBD) with two factors and three replications.

Data Collection

Five (5) plants per spacing were selected randomly for collection of data and the following parameters were evaluated:

Fruit Size (mm). Fruit size was the basis for marketability of strawberries. Five plants (5) were tagged in each spacing for data collection. Fruit size, measured in terms of length and width, was taken using digital vernier caliper in millimeter (mm).

Fruit Yield (g). Fruit yield was taken by weighing each fruit from each plant spacing with digital balance in gram (g).

Total Soluble Solids (Brix %). Total Soluble Solid (TSS) measures the sugar content of fruit juices using refractometer. Five (5) fruits per spacing were selected and their juice was extracted to measure the TSS using digital portable refractometer (model# LH-T80). Strawberry juice was put on the prism of the refractometer covering the lens and the reading was taken in Brix %.

Chlorophyll Content. Chlorophyll measurement can be utilized as an indirect indicator of nutrient levels. Spad-502 chlorophyll meter (Minolta Camera, Japan) was used to measure the chlorophyll content of five tagged plants. Chlorophyll content was measured from the mature and expanded leaves.

Taste and Color (Scale). Fruit color and taste were measured to obtain data for fruit quality, which was done by developing a scale described in Table 2. The fruit color was evaluated by visual basis, while taste was assessed based on the level of sweetness, bitterness, or sourness by the selected respondents. Five (5) random persons with different demographic profile evaluated the five fruits from each replication and then their average was computed for statistical analysis.

Table 2. Strawberry color and taste chart.

Color		Taste	
Dark red	4	Sweet	2
Red	3	Sour	1
Light red	2	Bitter	0
Pink	1		

Statistical Analysis

The collected data were analyzed by using a software package (STATISTIX 8.1), while the means were compared by using the least significant difference (LSD) test at 5% probability level.

RESULTS

Chlorophyll Content

Statistical analysis of data regarding chlorophyll content at reproductive stage showed significant effect in growing media but not for spacing and media × spacing (Table 3). The highest chlorophyll content (12.53) was observed in soil + peat moss, while the lowest chlorophyll content (9.12) was observed in soil + poultry waste (Table 10). Soil + poultry waste and combination of all media also showed better results with respect to chlorophyll content.

Table 3. Analysis of Variance of chlorophyll contents for strawberry at vegetative stage.

Source of Variance	Degree of Freedom	SS	MS	F	p
Replication	2	60.5	30.2		
Treatments	4	72.9	18.2	3.6	0.0173
Spacing	2	6.7	3.3	0.67	0.5209
Treatment × Spacing	8	30.3	3.7	0.75	0.6474
Error	28	141.7	5.0		
Total	44	312.235			

Grand Mean = 11.364
CV = 19.80
***Significant (p<0.05)**
^{NS}Non-significant (p>0.05)

TSS

Statistical analysis of data regarding TSS showed significant result for growing media but not for spacing and media × spacing (Table 4). The highest TSS value (8.45 ^{0}Brix) was observed in peat moss; other treatments showed similar results and there was no significant difference among them. Overall, the lowest TSS was observed in soil (Table 10).

Table 4. Analysis of Variance for total soluble solids of strawberry fruit.

Source of Variance	Degree of Freedom	SS	MS	F	p
Replication	2	7.5	3.7		
Treatments	4	16.0	4.0	4.96	0.0038
Spacing	2	0.4	0.2	0.27	0.7624
Treatment × Spacing	8	3.9	0.4	0.61	0.7604
Error	28	22.6	0.81		
Total	44	50.6724			

Grand Mean = 7.3604
CV = 12.23
***Significant (p<0.05)**
^{NS}Non-significant (p>0.05)

Yield Per Plant

Statistical analysis of data regarding yield per plant spacing showed significant result for media and media × spacing. Soil + peat moss showed excellent result as compared to other media used (Table 5). The highest yield (531.56 g) per plant was observed in soil + peat moss, while the lowest (260.17 g) was observed in soil + peat moss + poultry waste + farm yard manure. Peat moss with 20 cm spacing showed best results in growing media and spacing interaction. As shown in Table 10, the highest yield (626.03 g) was observed in peat moss + soil while the lowest was observed in soil (160.53 g).

Table 5. Analysis of Variance for yield per plant of strawberry at reproductive stage.

Source of Variance	Degree of Freedom	SS	MS	F	p
Replication	2	5637	2818		
Treatments	4	438825	109706	18.79	0.043
Spacing	2	5228	2614	0.45	0.76
Treatment × Spacing	8	116950	14619	2.50	0.03
Error	28	163511	5840		
Total	44	730151			

Grand Mean = 349.51
CV = 21.86
***Significant (p<0.05)**
^{NS}Non-significant (p>0.05)

Fruit Color

Results regarding fruit color showed highly significant results in growing media treatments, while plant spacing and growing media x plant spacingwere non-significant (Table 6). Dark red color was observed the greatest in soil + peat moss and the least in soil. Fruit should be fully colored *i.e.*, without white or green tips. Red color was observed the greatest in soil + peat moss (3.75) and the least in soil (2.30) (Table 10, Figure 1).

Table 6. Analysis of Variance for color of strawberry fruit.

Source of Variance	Degree of Freedom	SS	MS	F	p
Replication	2	0.4	0.2		
Treatments	4	12.3	3.1	22.49	0.00
Spacing	2	0.1	0.07	0.57	0.56
Treatment × Spacing	8	1.4	0.18	1.32	0.27
Error	28	3.8	0.13		
Total	44	18.3000			

Grand Mean = 2.9833
CV = 12.44
***Significant (p<0.05)**
^{NS}Non-significant (p>0.05)

Fruit Taste

Results regarding fruit taste showed high significance in growing media but not in plant spacing and media x spacing (Table 7). Sweet taste was observed the greatest in peat moss and the least in soil + poultry waste. In strawberry, flavor was developed via ripening process. Highest sugar content and flavor was obtained at full ripened stage. At harvesting time, strawberries were bright in color. Loss in water content causes the fruit to become wilted and dull. Sweet taste was found the greatest in soil + peat moss (1.83) and the lowest in soil + poultry waste (1.02) (Table 10, Figure 1).

Table 7. Analysis of Variance for taste of strawberry fruit.

Source of Variance	Degree of Freedom	SS	MS	F	*p*
Replication	2	0.26	0.13		
Treatments	4	3.34	0.83	21.99	0.00
Spacing	2	0.01	0.009	0.26	0.77
Treatment × Spacing	8	0.25	0.03	0.85	0.56
Error	28	1.06	0.03		
Total	44	4.95278			

Grand Mean = 1.4278
CV = 13.65
***Significant (p<0.05)**
NSNon-significant (p>0.05)

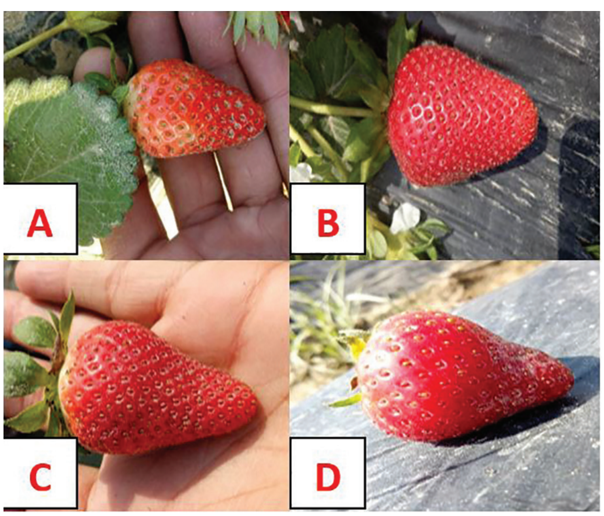

Figure 1. Effect of the different treatments on the taste and color of strawberry fruits: (A) T0-Pink, sour; (B) T4-Red, sweet; (C)T3-Light red; bitter; and (D) T1-dark red, sweet.

Fruit Size

Statistical analysis of data regarding the length of fruit at reproductive stage showed significant result in growing media (Table 8). Table 10 shows the greatest fruit length in soil + peat moss (39.14) and the least in soil (25.94).

Statistical analysis of data regarding width of fruit at reproductive stage showed significant result in growing media (Table 9). The greatest fruit width was observed in soil + peat moss (28.16), while the least was observed in the combination of all media (21.14) (Table 10).

Table 8. Analysis of Variance for length of strawberry fruit.

Source of Variance	Degree of Freedom	SS	MS	F	*p*
Replication	2	10.60	5.30		
Treatments	4	1098.48	274.6	41.77	0.00
Spacing	2	4.43	2.21	0.34	0.71
Treatment × Spacing	8	30.78	3.84	0.59	0.78
Error	28	184.09	6.57		
Total	44	1328.39			

Grand Mean = 29.372
CV = 8.73
***Significant (p<0.05)**
NSNon-significant (p>0.05)

Table 9. Analysis of Variance for width of strawberry fruit.

Source of Variance	Degree of Freedom	SS	MS	F	*p*
Replication	2	8.25	4.12		
Treatments	4	313.7	78.44	31.41	0.00
Spacing	2	15.4	7.70	3.09	0.06
Treatment × Spacing	8	26.7	3.34	1.34	0.26
Error	28	69.9	2.49		
Total	44	434.098			

Grand Mean = 22.950
CV = 6.89
***Significant (p<0.05)**
NSNon-significant (p>0.05)

Table 10. Effects of growing media and plant spacing on the chlorophyll content of strawberry.

Chlorophyll Content				
Treatments	**Spacing**			
	S_1	**S_2**	**S_3**	**Mean**
T_0	11.16	11	10.14	**10.77AB**
T_1	11.04	13.55	13.01	**12.53A**
T_2	9.19	9.8	8.38	**9.12B**
T_3	14.15	11.86	10.54	**12.18A**
T_4	11.63	12.75	12.19	**12.19A**
Mean	**11.437**	**11.798**	**10.857**	

T_0 – soil, **T_1** – soil + peat moss, **T_2** – soil + poultry waste, **T_3** – soil + FYM, **T_4** – soil + peat moss + FYM + poultry manure
S_1 = 20 cm, **S_2** = 30 cm, **S_3** = 50 cm
LSD value for treatment: 2.1724
LSD value for spacing: NS
LSD value for treatment x spacing: NS

Table 11. Effects of growing media and plant spacing on the TSS of strawberry.

Total Soluble Solids (TSS)				
Treatments	**Spacing**			
	S_1	S_2	S_3	**Mean**
T_0	6.92	7.04	6.76	**6.91^B**
T_1	8.86	8.25	8.24	**8.45^A**
T_2	6.88	6.46	7.40	**6.91^B**
T_3	7.86	7.53	7.26	**7.55^B**
T_4	6.54	6.80	7.56	**6.96^B**
Mean	**7.412**	**7.22**	**7.444**	

T_0 – soil, T_1 – soil + peat moss, T_2 – soil + poultry waste, T_3 – soil + FYM, T_4 – soil + peat moss + FYM + poultry manure
S_1 = 20 cm, S_2 = 30 cm, S_3 = 50 cm
LSD value for treatment: 0.8691
LSD value for spacing: NS
LSD value for treatment x spacing: NS

Table 12. Effects of growing media and plant spacing on the yield of strawberry.

Yield per Strawberry Plant				
Treatments	**Spacing**			
	S_1	S_2	S_3	**Mean**
T_0	160.53^f	310.37^{de}	355.60^{cde}	**275.50^C**
T_1	626.03^a	478.48^{bc}	489.00^b	**531.56^B**
T_2	369.27^{bcd}	355.53^{cde}	394.23^{bcd}	**373.01^C**
T_3	359.05^{cde}	294.80^{de}	269.27^{def}	**307.71^{BC}**
T_4	266.73^{def}	232.30^{ef}	281.49^{def}	**260.17^C**
Mean	**356.32**	**334.30**	**357.92**	

T_0 – soil, T_1 – soil + peat moss, T_2 – soil + poultry waste, T_3 – soil + FYM, T_4 – soil + peat moss + FYM + poultry manure
S_1 = 20 cm, S_2 = 30 cm, S_3 = 50 cm
LSD value for treatment: 73.791
LSD value for spacing: NS
LSD value for treatment x spacing: 127.81

Table 13. Effects of growing media and plant spacing on the taste of strawberry.

Taste				
Treatments	**Spacing**			
	S_1	S_2	S_3	**Mean**
T_0	1.50	1.25	1.50	**1.41^{BC}**
T_1	1.83	1.83	1.83	**1.83^A**
T_2	0.91	1.16	1.00	**1.02^D**
T_3	125	1.33	1.25	**1.27^C**
T_4	1.50	1.58	1.66	**1.58^B**
Mean	**1.40**	**1.43**	**1.45**	

T_0 – soil, T_1 – soil + peat moss, T_2 – soil + poultry waste, T_3 – soil + FYM, T_4 – soil + peat moss + FYM + poultry manure
S_1 = 20 cm, S_2 = 30 cm, S_3 = 50 cm
LSD value for treatment: 0.1882
LSD value for spacing: NS
LSD value for treatment x spacing: NS

Table 14. Effects of growing media and plant spacing on the color of strawberry.

Color				
Treatments	**Spacing**			
	S_1	S_2	S_3	**Mean**
T_0	2.41	2.00	2.25	**2.30**
T_1	3.83	3.58	3.83	**3.75^A**
T_2	2.50	2.58	2.66	**2.50^C**
T_3	3.50	3.25	3.08	**3.27^B**
T_4	2.75	3.25	3.25	**3.08^B**
Mean	**2.95**	**2.93**	**3.06**	

T_0 – soil, T_1 – soil + peat moss, T_2 – soil + poultry waste, T_3 – soil + FYM, T_4 – soil + peat moss + FYM + poultry manure
S_1 = 20 cm, S_2 = 30 cm, S_3 = 50 cm
LSD value for treatment: 0.1750
LSD value for spacing: NS
LSD value for treatment x spacing: NS

Table 15. Effects of growing media and plant spacing on the length of strawberry.

Length				
Treatments	**Spacing**			
	S_1	S_2	S_3	**Mean**
T_0	26.16	25.65	26.02	**25.94^B**
T_1	39.04	39.57	38.83	**39.14^A**
T_2	29.32	25.14	27.12	**27.19^B**
T_3	26.94	28.34	28.96	**28.08^B**
T_4	26.92	25.99	26.54	**26.48^B**
Mean	**29.67**	**28.94**	**29.49**	

T_0 – soil, T_1 – soil + peat moss, T_2 – soil + poultry waste, T_3 – soil + FYM, T_4 – soil + peat moss + FYM + poultry manure
S_1 = 20 cm, S_2 = 30 cm, S_3 = 50 cm
LSD value for treatment: 1.5259
LSD value for spacing: NS
LSD value for treatment x spacing: NS

Table 16. Effects of growing media and plant spacing on the width of strawberry.

Width				
Treatments	**Spacing**			
	S_1	S_2	S_3	**Mean**
T_0	21.94	22.24	23.02	**22.40^B**
T_1	29.82	28.69	25.97	**28.16^A**
T_2	22.58	21.92	20.06	**21.52^B**
T_3	22.26	21.20	21.06	**21.51^B**
T_4	21.88	20.028	21.25	**21.14^B**
Mean	**23.70**	**22.87**	**22.27**	

T_0 – soil, T_1 – soil + peat moss, T_2 – soil + poultry waste, T_3 – soil + FYM, T_4 – soil + peat moss + FYM + poultry manure
S_1 = 20 cm, S_2 = 30 cm, S_3 = 50 cm
LSD value for treatment: 1.208
LSD value for spacing: NS
LSD value for treatment x spacing: NS

DISCUSSION

Growing strawberry in soil culture such as in the field is challenging. The number one problem is the threat of pests and diseases in soil. In order to grow strawberry with less problems, different substrates for soilless culture such as peat moss, coconut coir, perlite, rockwool, and pine bark had been used. This study had similar results with the previous study of Jafarnia *et al*. (2010), which was about the effect of growing media on the yield and quality of strawberry using a different cultivar and in hydroponic culture (i.e., not soil-based). It was mentioned in the study that peat moss was the best growing media for soilless culture of strawberries in Iran.

In the case of Pakistan, it was evaluated in the current study that peat moss was also proven as the best growing media for soil-based culture of strawberries – as evidenced in their results. Strawberry plants tested showed better results when grown in peat moss, with the highest chlorophyll content of 12.53. Chlorophyll content can be used to diagnose plant nutrient status. If strawberries can achieve high chlorophyll content, they can be considered to have higher available nutrients when grown in the presence of peat moss.

Peat moss is considered as an optimal organic amendment to improve the physical properties of upland soils, such as in the case for blueberry cultivation due to its low pH, fine texture, and good water retention ability (Spiers 1986). Hence, the high chlorophyll content in strawberry grown in peat moss implies that high nutrients status can be attributed to the ability of peat moss to provide good growth conditions for strawberry. Peat moss adjusted the pH of the soil by lowering it, thus providing optimum pH for strawberry production. Strawberries grow best when provided with at least six hours of direct sun daily, regular irrigation, and slightly acidic soil. Moreover, the peat moss also enhances the soil texture by making the medium fine, which can be suitable for strawberries. Meanwhile, peat moss aids in improving the water retention ability of the soil, which probably led to high nutrient availability for the tested strawberries grown in peat moss and soil combination.

Chlorophyll is one of the most important biochemical parameters of plants and is usually an indicator of plants' nutritional stress, photosynthetic capacity, and health status; therefore, it is an important information parameter in research on crop quality monitoring, ecosystem productivity estimation, carbon cycles, etc. Fast and non-destructive chlorophyll content estimation is an important field of application for evaluation of plant health and yield parameters (Liu *et al*. 2014).

TSS (8.45) was also observed to be highest in peat moss amendment. According to Voća *et al*. (2008), TSS is very important in determining strawberry fruit quality. Strawberry is a delicious, low-energy food and a well-known source of vitamin C. Besides ascorbic acid, polyphenols are often discussed for their positive effect on human health. Strawberries contain several bioactive phytochemicals, including anthocyanins, flavonols, flavan-3-ols, and phenolic acids. Anthocyanins are natural pigments responsible for a wide range of red fruits. Antioxidant capacity in berries seems to be mostly due to the activity of phenolic compounds such as anthocyanins and antioxidative vitamins (mainly vitamin C). Antioxidant capacity of fruits results mainly from phenolics, particularly flavonoids. Flavonoids have been demonstrated to have anti-inflammatory, antiallergenic, antiviral, anti-aging, and anticarcinogenic activity. The desirable range of TSS for strawberries is 7–12. TSS of T_4 strawberries grown in soil + peat moss had the highest TSS value of 8.45, while the rest of the treatments had TSS of 6.91–7.55.

The best fruit yield and fruit quality were observed in strawberries grown in soil + peat moss. This observation was similar to the study by Al-Raisy *et al*. (2010), which focused on the effects of column sizes and media on the yield and fruit quality of strawberry under hydroponic vertical system in Oman. According to the study, peat moss improved the fruit yield and fruit quality of strawberries even in soil-based culture. This study promotes organic farming such as the application of organic soil amendments system, which does not ensure its sustainability. To be sustainable, strawberry production must result to adequate yield, be profitable in terms of fruit size and fruit quality, protect the environment, conserve resources, and be managed in a socially responsible way.

It has been claimed that organic production systems are less efficient, pose greater health risks, and typically yield less than conventional or integrated systems. Conversely – in the study of Abdel-Mawgoud *et al*. (2010) – it was proven that organic farming can produce higher yield and good fruit quality, which implies better marketability. However, the plant spacing used in their study was 30–50 cm, which was different from 20 cm used in this study. Previous literature showed that strawberries grown in rows with 45 cm intra-row spacing had significantly higher number of both flowers and fruits compared to strawberries grown in rows with 25 cm intra-rows spacing, while strawberries grown using 25 cm intra row spacing showed a better performance on raised beds than in rows under field conditions. Strawberries grown in wider spacing shows more biomass in their leaves compared with strawberries grown in closer spacing (Abdel-Mawgoud *et al*. 2010).

Media with organic soil additives were tested with different plant-to-plant spaces and showed significant results for peat moss as compared with poultry waste, farm yard manure, and soil alone. A comparison of the results of this study with published literatures established its originality since cultivar Chandler, which was used in the experiments of this study, has not been studied extensively. Different strawberry cultivars have different reactions to plant spacing and soil type and therefore, cultivars are important in determining performance – indicating the need to test growing system interactions in judgments at a range of different sites (Crisp *et al*. 1988).

CONCLUSION

Strawberry (cultivar Chandler) is best adapted to soil amended with peat moss. Peat moss has been established as the best growing media for soil-based culture of strawberries, as evidenced in our results. Strawberry plants tested showed better results when grown in peat moss with highest chlorophyll contents of 12.53. Chlorophyll content can be used to diagnose plant nutrient status. If the strawberries can achieve high chlorophyll content, they can be considered to have higher available nutrients when grown in the presence of peat moss. Peat moss in soil combination also enhanced the fruit yield, fruit quality, fertility, and overall production of strawberries. Organic amendments such as poultry waste and farm yard manure are therefore not advised for strawberry production due to the significantly lower results in all parameters tested. The yield per plant spacing for strawberry is 20 cm. Plant spacing is important to avoid overcrowding, which may reduce yields and also quality of the fruits produced because of competition for light and soil nutrients. Therefore, it is concluded that peat moss combined with soil and 20 cm plant-to-plant spacing improve the production of strawberry (cultivar Chandler).

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