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Research Article

Changes in Vegetative and Reproductive Growth and Quality Parameters of Strawberry (*Fragaria* × *ananassa* Duch.) cv. Chandler Grown at Different Substrates

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Growth substrates (polyester wool, rice husk, and wheat straw), along with soil as control treatment, were compared for vegetative growth, yield, and quality of strawberry cv. Chandler. All growth substrates tested showed good results in terms of growth rate as compared with control. Strawberry plants grown in polyester wool showed the highest (89.50%) survival rate as compared to rice husk (70.50%), wheat straw (64.63%), and control (67.56%). Moreover, a significant increase was observed among number of flowers, fruits, and yield in plants grown in polyester wool. Besides, a significant high amount of total soluble solids (TSS) (12.38 oBrix), titratable acidity (TA) (1.21%), ash (0.72%), vitamin C (37.39 mg/100 g), total carotenoids (3.90 μg/100 g), and total anthocyanins (3.47 cyanidine-3-glucoside/100 g) was recorded in fruits grown in polyester wool as compared to control. From these results, it can be concluded that the use of polyester wool as a growth substrate for strawberries can give higher yield and better fruit quality.

1. Introduction

Strawberry (*Fragaria* × *ananassa* Duch.) is a high value crop which is well known due to its colour, taste, and nutritional value which is increasing its economic importance [1]. These small fruits serve as an important source of different minerals and vitamin C and are also rich in antioxidants [2, 3]. Because of their high nutritional contents and economic importance, cultivars and advanced cultivation techniques are gaining importance in order to meet growing market demand. Under traditional growing system, strawberries are grown from replanted runners season after season in the same fields. This technique causes vulnerability to soilborne diseases such as *Verticillium* wilt, *Phytophthora* crown and root rot, black root rot, and charcoal rot caused by *Verticillium dahliae*, *Phytophthora cactorum*, *Cylindrocarpon destructans,* and *Macrophomina phaseolina*, respectively, in different strawberry cultivars [4, 5].

Different chemical disinfectants such as chloropicrin and methyl bromide fumigants have been used in the past to lessen the effect of soilborne pathogens and diseases [6]. However, these days people are becoming very conscious about side effects of synthetic fungicides and chemicals due to their hazardous effects on health. Further, these chemicals are dangerous for the overall environment as well. These concerns have resulted in efforts to phase out most of the chemicals around the world [7, 8]. The use of 1, 3-dichloropropene and chloropicrin or their mixtures has also been subjected to granting of exceptional uses depending on the crop, soilborne pathogen, and production area [8]. Therefore, there is a need to find alternatives to overcome these disease problems and maintain cultivation systems for strawberries with maximum yield.

Soilless culture is considered, the best candidate for production of strawberry because it tends to be less prone to diseases. This system can fit higher plant density in a small area than the traditional system with less use of water and fertilizer [9]. Moreover, this system also possesses high water-holding and retention properties when compared with mineral soils. Therefore, in recent past due to having large porosity, being lighter in weight, being free from pests and pathogens, and having less chemical complexes, many soilless substrates (peat, gravel, sand, rockwool, perlite, etc.) have been used for growing different horticultural and ornamental plants [10, 11].

Strawberry is also grown successfully in soilless culture; however, the dynamics of nutritional value of strawberries are highly dependent on the cultural media, environmental conditions, and cultivation techniques [12]. Several studies reported the role of diverse growing substrates on yield and overall quality of fruits [1, 5]. Four pepper cultivars grown in peat or in mixture media [peat + perlite + sand (1 : 1 : 1)] under greenhouse conditions showed that mixture media significantly improved fruit length, diameter, and weight in all cultivars as compared with peat. However, fruit quality parameters such as ascorbic acid content and total soluble solids were found higher in peat grown plants than the mixture media [13]. Similarly, an earlier study reported that when cucumber plants were grown at four different growing media, including peat, perlite, rice hull, and a mix substrate (perlite and rice-hull 50 : 50 *v*/*v*), results showed that substrates had significant effects on plant growth, total fruit yield, marketable fruits, and fruit weight, while no significant differences were observed among substrates in terms of fruit quality such as fruit length, diameter, and total soluble solids [14].

However, to our knowledge no studies have been done to evaluate the nutritional composition of strawberry fruits with respect to the nature of substrates. As growing substrate is a crucial feature in determining the nutrient and water uptake efficiency of plant which shows a significant role in manufacturing different biochemical compounds, we believe that this is an important question.

The current study was designed to evaluate the effect of four substrates on vegetative and reproductive growth and quality of fruits with special attention given to pH, total soluble solids, and titratable acidity which are responsible for flavour and taste development in strawberries. Further, secondary metabolites such as phenolics, flavonoids, carotenoids, and anthocyanins were also quantified during the experiment as these are associated with health promoting properties.

2. Materials and Methods

2.1. Experimental Details and Plant Material. The current study was done during 2018-2019 in the Department of Horticulture, Faculty of Agriculture, University of Poonch Rawalakot, Azad Jammu and Kashmir. Results reproducibility was confirmed by two experimental trials. The first trial took place from February to July 2018 and the second from February to July 2019 for all the parameters tested. In this study, different growth media were tested for cultivating strawberries. Strawberry runners of cv. Chandler were purchased from Mountain Agriculture Research Center Juglot, Gilgit-Baltistan, and transplanted to small plastic pots (12 inch). Based on the previous information reported, three different growing substrates were selected for growing of these runners. Each treatment was replicated three times and ten pots per replicate were filled in a ratio of 1 : 1 *v*/*v* (growing media: soil) with each of the growing media (polyester wool, rice husk, and wheat straw). Pots filled with only soil served as control. One runner per pot was planted. Physiochemical analysis of soil (preexperiment) which was used for filling of pots and pH of different growth substrates was done at Horticulture Lab, University of Poonch Rawalakot, and results showed that the soil was suitable for growing of strawberry plants (Table 1).

2.2. Field Site Description. Strawberry plants were planted in plastic pots and placed under shade at the Experimental Farm of the Faculty of Agriculture, University of the Poonch Rawalakot, Azad Jammu and Kashmir (latitude 33°51′32.18″N, longitude 73° 45′34.93″E). Shade was provided with polyethylene sheet (PE 200 μm). For this experiment, the pots were placed 15 cm apart. Fertilizers such as farm yard manure containing 0.5% N, 0.2% P_2O_5, and 0.5% K_2O were mixed with each growing media in a ratio (1 : 1) and urea 0.5 g in one liter of water was applied after one month of transplanting and then at fifteen days interval till harvest. Other agronomic practices such as irrigation were done twice in a week (200 ml per pot), and weeding was also done in order to ensure better growth and quality of strawberry plants. Data regarding vegetative growth, reproductive growth, and quality parameters of strawberry were recorded as mentioned below.

2.3. Vegetative and Reproductive Growth Parameters. Thirty plants from each treatment were used for data collection. Vegetative and reproductive growth were determined on the basis of various parameters. After one month of transplanting strawberry runners, survival rate was

Table 1: Physicochemical properties of soil before planting strawberry runners and pH of different growth substrates.

Parameters	Average content
Total N (%)	0.016
Available P (mg kg^{-1})	5.66
Available K (mg kg^{-1})	96.67
Soil organic matter (%)	0.33
Sand (g kg^{-1})	450
Silt (g kg^{-1})	260
Clay (g kg^{-1})	280
pH (soil)	7.4
pH (polyester wool)	8.5
pH (rice husk)	5.8
pH (wheat straw)	6.6

observed by calculating the number of plants from each treatment that survived divided by the number of plants originally planted. Leaf area was measured using a measuring scale at the time of harvest. The number of runners per plant was counted at the end of experiment. Days to first flower, fruits per plant, and days to harvest at commercial ripeness (>75% of the surface showing red colour) [1] were also recorded. Chlorophyll a, *b,* and total were measured by destructive sampling as given by Zahid et al. [15]. Overall yield per plant was measured after weighing harvested fruits from each plant and was expressed in grams. Fruit weight (01 fruit) expressed in grams (g) was determined using digital weighing balance (Model: Shimadzu A × 200, Japan) and average was taken. Diameter (01 fruit) expressed in millimeter (mm) was measured by using vernier calliper (Model: Insize SR44), and the average was taken.

2.4. Fruit Quality Parameters. A mixture of 300 g strawberry fruits from each treatment was used in triplicate to measure different fruit quality parameters. Fruits were kept in zip lock poly bags and were taken to Horticulture Lab, University of Poonch Rawalakot. Fruits were washed with purified water, air dried, and used for various analysis. Total soluble solids (TSS) were measured using method of Association of Official Analytical Chemists [16] by using hand refractometer (Model: Kyoto Company, Japan) and expressed in percentage. Titratable acidity (TA) was determined through titration method [17]. Briefly, the filtrate (5 ml) with 2-3 drops of 0.1% phenolphthalein solution as an indicator was titrated using 0.1 N NaOH to a pink endpoint. TA was measured in relation to ascorbic acid by using the following formula and expressed as the percentage:

$$\text{TA\%} = \frac{\text{ml of sodium hydroxide used} \times 0.1\,\text{N} \times \text{equivalent weight of ascorbic acid}}{\text{weight of sample} \times \text{volume of aliquot}}. \tag{1}$$

pH of extracted fruit juice was determined according to the method of AOAC [18] using a pH-meter (Model: WTW 82362 Inolab, Germany). pH-meter was calibrated with pH 4.0 and pH 9.0 buffers before taking observations. Electrode was cleaned and dried before recording data for each sample. Total phenolic contents were measured using spectrophotometer (Model: UV 4000, ORI, Reinbeker, Hamburg, Germany) and a method given by Maqbool et al. [19]. Mixture was prepared using 10% Folin–Ciocalteau's Reagent (0.5 ml), 7.0% sodium carbonate solution (1.5 ml), and aqueous extract (0.1 ml). Purified water was added to make volume of mixture up to 10 ml. This mixture was incubated at 40°C for 2 hours, and the absorbance was measured at 750 nm using spectrophotometer (Model: UV 4000, ORI, Reinbeker, Hamburg, Germany). Obtained results were presented as μg of gallic acid/g fresh weight (FW) of fruit. Total flavonoids were measured according to the method given by Maqbool et al. [19], and the results were expressed as mmol quercetin/100 g FW. Ash content was determined by burning 0.5 g of dried fruits at 600°C in electric muffle furnace (Model: SX-2-5-10) for three hours [20]. Ash content was calculated by the difference observed in weight [1]. Crude fiber was determined using the standard method given by AOAC [21]. Fruit sample (5 g) was collected and dried in an oven and then digested with 1.25% sodium hydroxide (NaOH) and sulfuric acid (H_2SO_4) solution. After that, samples were washed, dried, and then placed in a furnace at temperature of 500 or 550°C until samples were converted into white ash. The fiber content was determined by using the formula

$$\text{Crude fibre} = \frac{(c-b)-(d-b)}{(a)} \times 100, \tag{2}$$

where a is the sample weight, b is the crucible weight, c is the sample weight before ignition, and d is the sample weight after ignition.

Total carotenoids were measured by crushing strawberry fruit (2 g) using mortar and pestle followed by mixing with 10 ml of chilled acetone [22]. Filtration of reaction mixture was done followed by separating of carotenoids from acetone using petroleum ether. Absorbance was then taken at 450 nm using spectrophotometer (Model: UV 4000, ORI, Reinbeker, Hamburg, Germany). Standard calibration curve was prepared using all-trans-β-carotene (Sigma Chemical Co., USA). Vitamin C was determined by using 2,6-dichlorophenol indophenol dye. Fruit juice (5 ml) plus 4% meta phosphoric acid (5 ml) was mixed, and the solution was titrated by using dye until the persistence of light pink colour. The results were expressed as mg/100 g FW of fruit. Total anthocyanin was measured using spectrophotometer (Model: UV 4000, ORI, Reinbeker, Hamburg, Germany) by pH dilution method [23]. Two buffers, that is, sodium acetate (pH-4.5) and potassium chloride (pH 1.0), were used for dilution of samples. The absorbance of each dilution sample was observed at 510 nm and 700 nm, respectively, using spectrophotometer. Anthocyanin pigment was recorded as mg of cyaniding-3-glucoside/liter using an extinction coefficient of 29,600 and molecular weight of 449.2. Antioxidant activity of strawberry samples was measured using the technique given by Molyneaux [24] with slight modifications. In this method, for measuring antioxidant activity, free-radical l, l-diphenyl-2-picrylhydrazyl (DPPH) was used. Mixtures of 50 μl-methanolic solution (diluted 1 : 6) of each extract was made by adding 0.1 mM methanolic solution of DPPH and placed in a dark place at room temperature to react with each other. Reduction in the absorbance of DPPH at 517 nm was recorded in gaps of time of 5 min until the absorbance stabilized for 30 min. DPPH radical scavenging activity of fruit extracts was measured by using the formula

$$\text{DPPH scavenging activity percentage} = \left(A_0 - \frac{A_s}{A_0} \right) \times 100, \quad (3)$$

where $-A_0$ is the absorbance of the treatment under control conditions and $-A_s$ is the absorbance of the sample taken for study.

2.5. Statistical Analysis. Experiment was set in a randomized complete block design (RCBD) with three replicates, and it was repeated twice, and results were pooled for analysis as the important outcomes of separate analysis showed almost parallel results across the trials. Collected data was subjected to analysis of variance (ANOVA) using statistical software (Statistix 8.1) [25] and means were compared using Tukey's test at $P < 0.05$.

3. Results

3.1. Effect of Different Substrates on Vegetative and Reproductive Growth Parameters of Strawberries. Results regarding survival percentage of strawberry plants showed significant differences ($P < 0.05$) among different growing media (Figure 1). The lowest survival percentage (64.63%) was noted in strawberry plants grown in wheat straw, while the highest survival percentage (89.50%) was noted in plants grown in polyester wool. However, a nonsignificant difference ($P > 0.05$) was observed in survival percentage of strawberry plants grown in rice husk (70.50%) and soil (67.56%).

On the bases of survival percentage results soil, polyester wool, rice husk, and wheat straw were used for further studies.

Different growing media showed a significant ($P < 0.05$) difference in terms of vegetative growth of strawberry cv. Chandler (Table 2). Maximum leaf area was noticed in plants grown in polyester wool, while minimum leaf area was observed in plants grown in soil, whereas nonsignificant difference ($P > 0.05$) was recorded between plants grown in rice husk and wheat straw. Significantly ($P < 0.05$) higher number of runners per plant were observed in polyester wool.

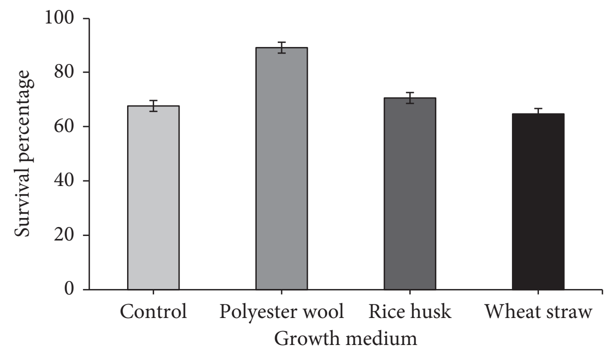

Figure 1: Effect of different growth substrates on survival percentage (%) of strawberry cv. Chandler. Vertical bars indicate standard error of means (±SEM) for three replicates.

Table 2: Effect of different growth substrates on vegetative growth of strawberry cv. Chandler.

Treatments	Leaf area (cm^2)	No. of runners
Soil (control)	40.63 ± 0.22 c	20.65 ± 0.40 bc
Polyester wool	61.46 ± 0.48 a	32.66 ± 0.46 a
Rice husk	53.30 ± 0.32 b	25.33 ± 0.18 b
Wheat straw	53.46 ± 0.26 b	22.34 ± 0.59 b

Note. Different letters in each column indicate significant ($P < 0.05$) difference among treatments, ±SD.

Results regarding days to first flower of strawberry plants revealed nonsignificant differences ($P > 0.05$) among different growing media (Table 3). All the plants took almost 52 to 57 days for appearance of first flower. Results regarding average number of flowers and average number of fruits per plant showed a significant ($P < 0.05$) difference among all treatments. Maximum number of flowers (29.73) and fruits (27.00) were recorded in plants grown in polyester wool, while minimum number of flowers (16.1) and fruits (14.60) were noted in plants grown in soil (Table 3). Rice husk and wheat straw statistically showed no difference for flowering and fruiting.

Results regarding number of days to harvest and yield per plant showed significant ($P < 0.05$) differences among treatments (Table 3). A minimum number of days to fruit harvest were recorded in polyester wool (115.6), whereas plants grown in soil took maximum number of days (132.4) for fruit harvesting. Similarly, maximum yield per plant (324.03 g) was found from plants grown in polyester wool, while minimum yield was recorded in plants grown in soil (163.52 g) (Table 3).

Results regarding chlorophyll showed significant ($P < 0.05$) differences among all substrates under study (Figure 2). The highest chlorophyll a, b, and total chlorophyll content were recorded in plants grown in polyester wool. In the case of chlorophyll b, plants grown in rice husk and wheat straw showed a nonsignificant ($P > 0.05$) difference with plants grown in soil.

Fruit characteristics in terms of weight of fruit and diameter of fruit were recorded for strawberries grown in different growth medium. A significant ($P < 0.05$) difference was recorded in weight of fruit and diameter of fruit of

Table 3: Effect of different growth substrates on reproductive growth of strawberry cv. Chandler.

Treatments	Days to first flower	No. of flowers	No. of fruits	Days to harvest	Yield (g)
Soil (control)	57.63 ± 0.15 a	16.10 ± 0.10 c	14.60 ± 0.21 c	132.40 ± 1.08 a	163.52 ± 1.70 c
Polyester wool	52.40 ± 0.37 a	29.73 ± 0.07 a	27.00 ± 0.08 a	115.60 ± 1.73 c	324.03 ± 4.34 a
Rice husk	50.90 ± 0.19 a	23.60 ± 0.21 b	21.80 ± 0.65 b	123.20 ± 1.67 b	283.03 ± 3.72 b
Wheat straw	52.46 ± 0.24 a	22.00 ± 0.17 b	20.43 ± 0.28 b	121.70 ± 1.75 b	275.13 ± 5.63 b

Note. Different letters in each column indicate significant ($P < 0.05$) difference among treatments, ±SD.

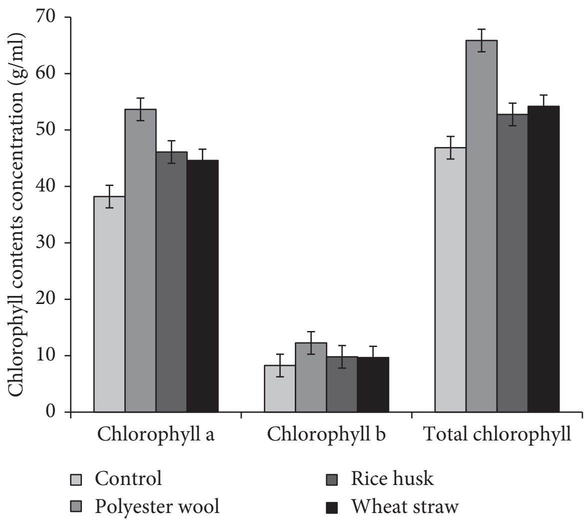

Figure 2: Effect of different growth substrates on chlorophyll contents concentration (g/ml) of strawberry cv. Chandler. Vertical bars indicate standard error of means (±SEM) for three replicates.

strawberries grown in different media (Figure 3). The highest fruit weight (19.2 g) was recorded in fruits grown in polyester wool, while the lowest weight of fruit was recorded in fruits grown in soil (13.9 g) (Figure 3(a)). Data regarding diameter of fruit showed that fruit grown in polyester wool had bigger sized fruits as compared to fruits grown in other growth medium (Figure 3(b)).

Our results are supported by correlation equation ($y = 0.2693x + 1.5783$; $R^2 = 0.9562$) between total chlorophyll content and weight of fruit which revealed that one unit increase in total chlorophyll content resulted in 0.2693 units increase in weight of fruit (Figure 4(a)). Similarly, correlation equation ($y = 0.296x + 2.674$; $R^2 = 0.8776$) between total chlorophyll content and fruit diameter revealed that one unit increase in total chlorophyll content resulted in 0.296 units increase in diameter of fruit (Figure 4(b)).

3.2. Effect of Different Substrates on Quality Parameters of Strawberries. Significant differences ($P < 0.05$) were observed among all treatments tested in terms of quality of strawberries (Table 4). Fruits obtained from plants grown in polyester wool showed higher TSS (12.38°Brix), TA (1.21%), pH (3.94), ash content (0.72%), and crude fiber content (2.69%), while fruits obtained from plants grown in rice husk and wheat straw were comparable with each other. The lowest amount of nutrients was recorded in fruits grown in soil (Table 4).

Significant differences ($P < 0.05$) were observed among treatments tested in terms of health-related compounds (Table 5). Fruits obtained from plants grown in polyester wool showed higher amounts of total carotenoids (3.90 μg/100 g FW), vitamin C (37.39 mg/100 g FW), total anthocyanins (3.47 mg cyaniding-3-glucoside/100 g FW), total flavonoids (8.08 mmol quercetin/100 g FW), total phenolics (8.60 μg gallic acid/g FW), and radical scavenging activity (94.3%) (Table 5), while fruits obtained from plants grown in rice husk and wheat straw were comparable with each other. The lowest amount of health-related compounds were recorded in fruits grown in soil (Table 5).

4. Discussion

4.1. Effect of Different Substrates on Vegetative and Reproductive Growth Parameters of Strawberries. The influence of growth media on the survival percentage of plants is highly dependent on bulk density and pH of growth media [26]. Low bulk density of soilless media results in low water holding capacity of media which results in low uptake of nutrients by the plants. Similarly, survival and growth of plants is also highly dependent on pH, aeration, and organic matter in growing media [27]. In this study, wheat straw possessed less pH (6.6) which had ultimately affected the uptake of nutrients and hence resulted in less growth. In case of polyester wool (pH: 8.5), the high survival percentage could be due to its high-water holding capacity which is helpful for better uptake of nutrients by the plants [5].

In a previous study, it was observed that vegetative growth of strawberry varied with the ecological conditions of substrate [28]. Therefore, the maximum leaf area and number of runners recorded in plants grown in polyester wool might be attributed to the fact that polyester wool had better water holding capacity than other substrates used during this study. Further, Ercisli et al. [27] also found similar results where they reported that good aeration and low water tension with high water holding capacity gave positive results on development and growth of strawberry roots. It has also been reported that strawberry can grow better in alkaline soils (pH: 7.2-8.8), whereas the pH of rice husk and wheat straw lied between 5.8 and 6.6 [29]. This low pH might be the reason for lower vegetative growth observed in strawberries grown in medium containing rice husk and wheat straw.

Chlorophyll is responsible for photosynthesis. Increase in chlorophyll content results in increased photosynthesis which has positive effects on crop growth and increases yield by reducing moisture loss [30].

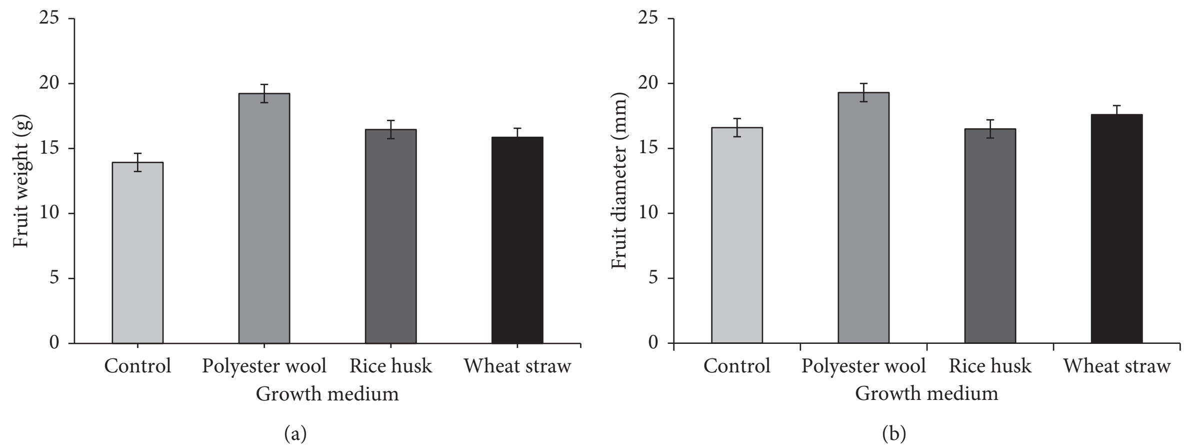

Figure 3: Effect of different growth substrates on (a) fruit weight g and (b) fruit diameter (mm) of strawberry cv. Chandler. Vertical bars indicate standard error of means (±SEM) for three replicates.

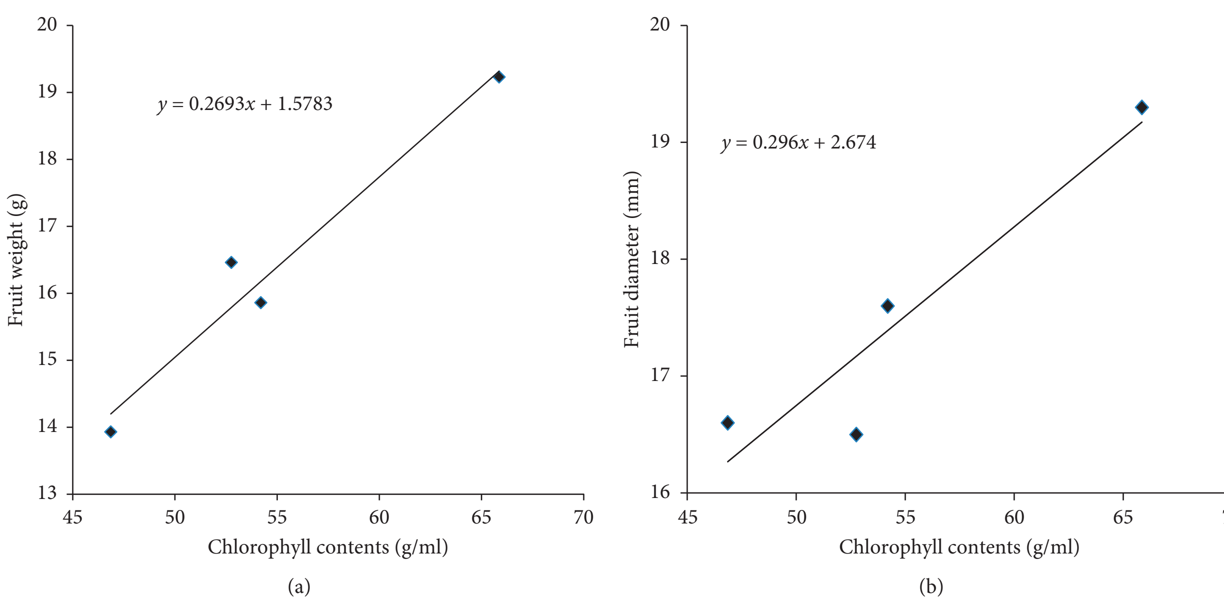

Figure 4: Relationship between chlorophyll contents: (a) fruit weight and (b) fruit diameter of strawberry cv. Chandler at $P < 0.05$.

Table 4: Effect of different growth substrates on proximate nutrients of strawberry cv. Chandler.

Treatments	TSS (Brix)	TA (%)	pH	Moisture (%)	Ash (%)	Fiber (%)
Soil (control)	7.36 ± 0.33 c	0.69 ± 0.03 c	3.94 ± 0.09 a	80.36 ± 2.06 b	0.54 ± 0.01 c	2.21 ± 0.06 c
Polyester wool	12.38 ± 0.36 a	1.21 ± 0.04 a	3.54 ± 0.06 c	91.76 ± 2.28 a	0.72 ± 0.01 a	2.69 ± 0.06 a
Rice husk	9.93 ± 0.41 b	1.07 ± 0.02 b	3.70 ± 0.11 b	85.00 ± 1.17 b	0.66 ± 0.02 b	2.43 ± 0.09 b
Wheat straw	9.16 ± 0.33 b	1.08 ± 0.07 b	3.73 ± 0.09 b	82.80 ± 1.55 b	0.65 ± 0.02 b	2.42 ± 0.06 b

Note. Different letters in each column indicate significant ($P < 0.05$) difference among treatments, ±SD; TSS = total soluble solids and TA = titratable acidity.

In our results, overall yield of strawberry depended on different growth substrates. The higher yield was obtained in plants grown in polyester wool. However, it is unclear that which chemical or physical factor had the most influencing role in plant growth and consequently the overall yield. Recent studies showed that microbial growth in soilless substrates showed a positive influence on roots of plants resulting in better plant growth [12].

Table 5: Effect of different growth substrates on health-related compounds of strawberry cv. Chandler.

Treatments	Phenolic (μg gallic acid/g FW)	Flavonoids (mmol quercetin/100 g FW)	Carotenoids (μg/100 g FW)	Vitamin C (mg/100 g FW)	Anthocyanins (mg cyanidine-3-glucoside/100 g FW)	Total antioxidants (% radical scavenging activity)
Control	4.97 ± 0.18 c	4.50 ± 0.19 c	1.16 ± 0.08 c	25.74 ± 0.99 b	0.98 ± 0.03 c	84.50 ± 2.90 c
Polyester wool	8.60 ± 0.70 a	8.08 ± 0.32 a	3.90 ± 0.44 a	37.39 ± 1.58 a	3.47 ± 0.18 a	94.30 ± 3.08 a
Rice husk	7.35 ± 0.32 b	6.22 ± 0.26 b	2.83 ± 0.15 b	28.55 ± 0.95 b	2.04 ± 0.14 b	89.90 ± 1.61 b
Wheat straw	6.90 ± 0.42 b	6.00 ± 0.58 b	2.86 ± 0.57 b	28.59 ± 1.98 b	2.01 ± 0.09 b	88.60 ± 2.89 b

Note. Different letters in each column indicate significant ($P < 0.05$) difference among treatments, ±SD; FW: fresh weight.

Fruit characteristics are highly correlated with chlorophyll content. It is generally believed that increase in leaf area which is active for photosynthesis is responsible for increase in fruit weight and size [9]. In our results, maximum weight and diameter of fruit could be due to the high chlorophyll pigment in plants grown in polyester wool.

4.2. Effect of Different Substrates on Quality Parameters of Strawberries. Different culture systems and phenotypes affect the nutrient quality of strawberries [31]. High acidity and high total soluble solids are responsible for good flavour [3]. Total soluble solids and acidity vary with change in genotypes of strawberries [9]. Difference in nutrient components of strawberry is highly dependent on growth media as the osmotic pressure in growth media affects the availability of nutrients to plants [5]. Results regarding ash and fiber in strawberry varied among different growth media which might be related to the availability of sugar content which are responsible for ascorbate synthesis. This precursor is necessary for enhancing the nutrient components in fruits [5].

Beneficial effects of fruits on the human body mainly depend on concentration of vitamin C, carotenoids, tocopherols, and flavonoids [32]. Differences in health-related compounds in strawberry grown in different growth substrates might be due to the fact that different bacteria grow in root zones of strawberries in soilless cultures [12]. These bacteria are responsible for the availability of wide range of substances (nitrogen, carbon, Fe, etc.) and enable plants to take nutrients from media in adequate amounts. Strawberries are a rich source of vitamin C and this content is 10 times higher than in apples and grapes [33]. Synthesis of vitamin C is genetic factor and tissue specific [34]. However, its synthesis is anabolic in plants and follow the L-galactose pathway which is related to photosynthetic activity of plants [5]. Increased chlorophyll content in plants grown in polyester wool resulted in increased vitamin C content in strawberry fruits which could be due to the higher photosynthetic rate [9]. Increased leaf area and high chlorophyll content in our results are responsible for the increased photosynthetic rate, thus helping in accumulation of vitamin C in fruits.

Total carotenoids are one of the most important antioxidants found in strawberries. It is reported that increase in total carotenoids is enhanced with the process of photosynthesis [35]. The process of photosynthesis occurs mainly due to the presence of chlorophyll, and it has been reported that chlorophyll and carotenoids are positively correlated with each other. Moreover, both the chlorophyll and carotenoids are derived from the same pathway which is 2-C-methyl-D-erythritol 4-phosphate (MEP). Therefore, they are strongly dependent on each other [36]. It is also believed that total carotenoids are helpful in contributing colour to the fruits at final stages of ripening. A similar trend was observed in tomato fruits where de novo synthesis of carotenoids occurred mainly due to transformation of chloroplasts to chromoplasts [37]. In this way, increased amount of total carotenoids in strawberry fruits grown in polyester wool could be associated with the increased rate of photosynthesis, which helped in accumulation of carotenoids in harvested fruits.

Flavonoids are also responsible for different antioxidant activities in the human body. Besides their beneficial human health effects, flavonoids also help reduce over ripening in fruits. Moreover, they are important group of plant secondary metabolites which help in accumulation of flavonols and flavones which are used to protect plants from different biotic and abiotic stresses [38]. Some particular flavonoids can play vital role in regulation of climacteric ethylene biosynthesis resulting in stimulation of fruits ripening [39]. In many fruits, flavonols are the main flavonoids at the beginning of fruit development and several studies demonstrated that high light intensity affected the expression of genes responsible for biosynthesis of flavonoids and consequently increased the amount of flavonols [40–43]. In a recent study by Yuan et al. [42], it was observed that the biosynthesis of flavonoids and accumulation of secondary metabolites in soybeans was dependent on many factors including the rate of photosynthesis. With the increase in rate of photosynthesis, there was a great increase in flavonoid contents which influenced the fruit colour and nutritional quality. Thus, increased amount of flavonoids in fruits grown in polyester wool could be linked with the increased rate of photosynthesis, which helped in accumulation of flavonoids in strawberry fruits.

Anthocyanins and phenols are also very significant health-related compounds found in strawberry. Strawberry is a rich source of polyphenols [44]. Some researchers advocated that polyphenols account for more than 50% of total phenols in strawberry [45]. In our results fruits grown in polyester wool showed the highest amount of total anthocyanins and total phenols which might be due to the increase in chlorophyll content. Similar results were obtained by Martínez et al. [9] where they observed higher amount of total anthocyanins and total phenols in strawberries grown in coir fiber. Further, they recorded that with the increase in SPAD values, there was an increase in total anthocyanins and total phenols. To confirm our findings, a study conducted by Pestana et al. [46] reported that lower SPAD values significantly reduced the amount of anthocyanins and total phenols in strawberry fruits. The changed amount of phenolic and anthocyanin compounds results in changed antioxidant activity which endorses the theory that the kind of growth substrate is vital for antioxidant capacity in strawberries [47]. In a recent study by Wysocki et al. [48], a higher yield as well as increased contents of polyphenols and anthocyanins were found in strawberry fruits from plants cultivated in the peat-coconut substrate. However, in this study, the increased contents in strawberry fruits obtained from plants grown in polyester wool growth substrate confirm that this substrate provided better conditions for plant development and assimilation of the assessed compounds.

5. Conclusions

Results of this study indicate that growth substrates had a great influence on vegetative and reproductive growth and quality indexes of strawberry cv. Chandler. These findings also suggest that polyester wool may serve as a valuable growth substrate for successful improvement in growth, yield, and quality of strawberry cv. Chandler. However, further studies should be carried out with different cultivars of strawberries to draw a general conclusion regarding the effect of growth substrates on vegetative and reproductive growth and quality. Consideration also needs to be given concerning the viability of expanding the use of polyester wool, the likely economic and environmental costs linked to its use and subsequent disposal, and sociocultural challenges to uptake.

Data Availability

All the relevant data have been provided in the manuscript. The authors will provide additional details if required.

Disclosure

Mehdi Maqbool is currently at Department of Horticulture, Faculty of Agriculture, University of Poonch Rawalakot, Azad Jammu and Kashmir, Pakistan.

Conflicts of Interest

The authors declare no conflicts of interest.

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