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RESEARCH ARTICLE

Impact of Different Shed Houses and Growing Media on Growth, Yield and Quality of Strawberry

Nazrul Islam • Ismail Hossain • Shormin Choudhury✉

Sher-e-Bangla Agricultural University, Faculty of Agriculture, Department of Horticulture, Dhaka/Bangladesh

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ABSTRACT

Partial controls of the microclimatic conditions have a major influence on plant growth and productivity. Moreover, plant growth is largely dependent on the physicochemical properties of the growing media. The purpose of this study was to see how different growing media and shade houses affected strawberry plant growth, yield, and quality attributes. The experimental treatments include net house, UV poly shade house, and open field (control) conditions; and three different growing media i.e., 50% soil + 50% cowdung, 50% soil + 50% vermicompost, and 50% soil + 50% cocopeat were studied. According to the findings, strawberries grown in a net house with cocopeat substrate had the highest chlorophyll content (SPAD value) (46.1), fruit yield (289.16 g plant^{-1}), total soluble solid (8.0%), reducing sugar (8.75 mg g^{-1}) and total anthocyanin (30.80 mg 100 g^{-1}). In contrast, fruits grown under UV poly shed with cocopeat substrate exhibited increased plant height (20.33 cm) and ascorbic acid (46.94 mg 100 g^{-1}). Vermicompost based growing media showed no satisfactory improvement in the reproductive growth characteristics of strawberry plants. Therefore, cocopeat based growing media and net house shade may be recommended to obtain better strawberry yield and quality.

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1. Introduction

The strawberry (*Fragaria x ananassa*) is a member of the Rosaceae family's genus Fragaria (Hancock, 1999). Strawberry is a short-day herbaceous perennial plant that grows well at temperatures ranging from 22 to 25 °C during the day and 7 to 13 °C at night (De & Bhattacharjee, 2012). Strawberries are valued for their taste and essential nutrition, and are rich in anthocyanins, and flavanols that are bioactive compounds. As well as preventing cardiovascular disease, inflammation, and some forms of cancers, with the advantages of slowing down aging (Miao et al., 2017). The intake of fresh strawberries per capita has risen from 0.90 kg in 1980 to 3.26 kg in 2018 (AgMRC, 2019). With ever-limiting resources of cultivated land, it is desirable to increase the yield of horticultural crops not only quantitatively, but also qualitatively.

The climate, which has a high degree of variability, is the most crucial factor in agricultural production because it can alter the atmosphere in which crops are grown (Iizumi & Ramankutty, 2015). It is necessary to measure the circumstances under which plants are grown and to take into account how environmental factors affect the fruit's quality (Martínez et al., 2017). Temperature and relative humidity are two environmental factors that have a significant impact (Rivera et al., 2017). The most significant environmental factor that affects the growth of cymes, flowers, and fruit is

✉ Corresponding author
E-mail address: shormin2000@gmail.com

temperature. The microclimate in the shed house was more conducive to the fruit crop's growth and yield attributes. The enhanced rate of photosynthate transfer from the vegetative component (source) to the reproductive organs (sink) may have boosted fruit size and weight, resulting in greater tomato fruit yield (Kuscu et al., 2014). Sugar-acid ratio, titratable acids, and pH varied between cultivars, suggesting that these traits may be heritable as they were less affected by environmental factors. Kumakura and Shishido (1995) observed that the fruit weight in the glasshouse dropped as the mean temperature increased.

The growing medium used has an effect on plant growth. Strawberries grow best in peat moss, rock wool, coir, perlite, or other mixtures. Growing media serves as both a growing medium and a source of plant growth nutrients. Soil is commonly used as a basic medium because it is the cheapest and easiest to obtain (Bhardwaj, 2013). Vermicompost provides adequate levels of oxygen to the roots, as well as adequate water storage and nutrient for the plants. Farmyard manure (FYM) has a high water retention capacity as well as adequate porosity.

These growing substrates are either single components or mixtures that provide water, air, and nutrients to plants (Olaria et al., 2016). In spite of that, the composition, particle size, pH, aeration, and ability to hold water and nutrients vary greatly between growing media (Oagile et al., 2016). The quality and performance of strawberries greatly depend on the growing media used. The requirement for special media is a critical step in ensuring the plant's efficient growth in the container, as their growth is heavily reliant on the physicochemical properties of the media used (Riaz et al., 2008).

Protected agriculture has expanded nowadays to help improve agricultural productivity. To date, there is not much research available on strawberry cultivation in the shade house. Limited work has been reported on strawberry cultivation regarding the application of growing media under different shades. Therefore, the study aimed to assess the response of different growing media and shade houses on plant growth, yield, and quality attributes of strawberries.

2. Materials and Methods

2.1. Plant Materials and Growing Conditions

During 2019-2020, the experiment was carried out at the Horticulture farm of Sher-e-Bangla Agricultural University in Dhaka, Bangladesh, under natural lighting conditions. The present investigation was carried out in three different shades i.e., net house, plastic shade house, and open field condition (control), and different growing media were used in different ratio i.e., Soil:Cowdung (1:1), Soil:Vermicompost (1:1), and Soil:Cocopeat (1:1). The total nitrogen (N) content was determined using the method of Bremner (1960), while the phosphorus (P) and potassium (K) concentrations (Table 1) were determined using the Motsara and Roy (2008) method. The recommended dose of fertilizers was applied insoluble form based on the nutrient condition of the growing media. The experiment was set up with six replications in plastic pots in a completely randomized design. Dhaka is located at 23°42′37″ N (Latitude), 90°24′26″ E (Longitude) and has an average elevation of 4 meters, according to the National Mapping Organization of Bangladesh. All fundamental cultural practices and plant protection techniques were applied uniformly across all plots throughout the experiment. Five plants were chosen at random from each replication for observations on growth, yield, and physicochemical parameters. Between November 2019 and March 2020, temperatures and relative humidity were measured in all environments to keep track of the actual environmental conditions that the plants were grown in (Table 2).

Table 1. Initial nutrient composition of the following substrates.

Growing media	Nutrients		
	N (%)	**P (%)**	**K (%)**
Cowdung	0.85	0.12	1.49
Cocopeat	0.41	0.81	1.32
Vermicompost	1.25	1.14	1.19

Table 2. Average monthly temperature and relative humidity (%) at 12 hours in different shade house and open field.

Month	12 hours					
	Open field		**UV poly shed**		**Net house**	
	Temperature (℃)	Humidity (%)	Temperature (℃)	Humidity (%)	Temperature (℃)	Humidity (%)
November, 2019	29.33	66.98	30.03	60.07	26.87	69.19
December, 2019	24.03	68.75	24.93	62.95	20.45	70.01
January, 2020	23.58	70.6	24.12	66.53	21.03	72.21
February, 2020	26.48	66.72	27.21	65.93	23.09	69.01
March, 2020	31.41	62.51	32.05	61.9	27.55	66.19

2.2. Measurement of Growth Parameters

Five plants in each treatment and replication were used to measure the height of the plant and the number of leaves at harvest. From the bottom to the top of the main plant, the height of the plant was measured.

2.3. SPAD Chlorophyll Meter Reading

An SPAD-502 chlorophyll meter was used to measure the chlorophyll content of the first fully expanded leaves (Minolta, Tokyo, Japan.). Measurements were taken from the middle of the leaf lamina of each treated and control plant.

2.4. Measurement of Yield and Yield Traits

The yield/plant (g) was calculated by adding the harvests from five plants in each treatment and replication. Strawberries were picked every two days for a total of five to seven pickings. The weight of fruits (g) from each selected plant was measured using an electronic top pan balance on each date of harvest. The number of fruits/plants was determined by counting the fruits that were ripe enough to be harvested.

2.5. Measurements of Quality Parameters

2.5.1. Total soluble solids content

A digital refractometer was used to determine the TSS content of strawberries (MA871, Romania). Using a dropper, a drop of strawberry juice was applied to the prism of the refractometer Total soluble solids were measured using a refractometer.

2.5.2. pH determination

Separate strawberry fruit juices from each treatment were filtered, and a digital pH meter was used to measure the pH (HI 2211, Romania).

2.5.3. Titratable acidity (TA %)

A 5 g sample was macerated with a mortar and pestle to determine titratable acidity. Then filtered and distilled water rendering 100 ml of total volume was added. In a conical flask, 10 ml of the stock solution was then added along with 2 drops of phenolphthalein. Titration of the solution was done using 0.1 N NaOH. Total acid content was determined in maleic acid equivalents and is reported as the mean value of triplicate analyses.

2.5.4. Vitamin C determination

The Vitamin C content of strawberries was determined using the Oxidation-Reduction Titration Method (Tee et al., 1988). 100 ml of a 5% oxalic acid solution were used to create the volume. For the titration, the dye solution 2, 6-dichlorophenol indophenol was used. The mean observations demonstrated how much dye was required to oxidize a particular quantity of an unknown concentration of a L-ascorbic acid solution using L-ascorbic acid as the known sample. The final point of titration, which lasted 10 seconds and required a 5 ml solution each time, was determined by the pink color. The reading from the burette was recorded.

2.5.5. Reducing sugars content

Determination of reducing sugars was based on the phenol-sulphuric acid method (DuBois et al., 1956). With deionized water, a total of 0.2 g fresh fruit was homogenized and the extract was filtered out. 2 ml of the solution was combined with 0.4 ml of 5% of phenol. Subsequently, the mixture was rapidly added to 2 ml of 98% sulphuric acid. The test tubes were allowed to keep at room temperature for 10 min and positioned for color development in a water bath at 30 °C for 20 min. Light absorption with the spectrophotometer was then measured at 540 nm. A blank solution was prepared in the same manner as described above, except that the fruit extract was replaced with distilled water. Reducing sugar content was expressed as mg g^{-1} fresh weight (FW).

2.5.6. Anthocyanin content

1.0 g fruit pulp mixed with 1 ml 85% ethanol + 15% HCl 1.5 N. After the extraction, 1 ml sample solution was taken and then diluted to 10 ml. The absorbance reading was taken at 535 nm. Then calculated the anthocyanin concentration as follows: Anthocyanin (mg per 100 g fresh weight) = (absorbance at 535 nm x volume of extraction solution x 100)/ weight of the sample in g x 98.2. The same procedure is used to prepare reference solutions as described above, except that the fruit extract is replaced with distilled water (Lapornik et al., 2005).

2.6. Statistical Analyses

A randomized complete block design (RCBD) was used in the experiments, with four replications for each treatment and five plants in each replicate. IBM SPSS Statistics 21 was used to conduct the statistical analyses (IBM Corp, Armonk, NY, USA). When $p<0.05$, the mean value across the treatments was regarded as statistically significant. The mean value among the treatments was considered to be statistically significant when. The mean±SE from the replicates was used to present all results. The graphs were created in Microsoft Excel. ANOVA was used to test the effect of the shade house, growing media, and their interaction on yield and biochemical parameters.

3. Results and Discussion

3.1. Environmental Conditions

The main environmental factor influencing the growth and development of short-day strawberry plants is temperature (Palencia et al., 2013). Our experiment revealed that the air temperature in UV poly shade was consistently higher than the conditions in the open field and net houses (Table 2). For photosynthesis in strawberries, ideal temperatures range from 15 to 23 °C (Hancock, 1991). Higher temperatures affect net photosynthesis more adversely than lower temperatures, leading to lower photosynthesis output above a certain temperature (Reddy et al., 1999). Relative humidity increases the net energy availability for crop growth and enhances crop survival under conditions of moisture stress. A relative humidity level of 65 to 75% during the day was considered to be optimal for good growth and yield of strawberries in the greenhouse (Lieten, 2000). In our experiment, the relative humidity was therefore at an optimum level in all the growing conditions.

3.2. Effect of Different Shade Houses and Growing Media on Plant Growth

Figure 1 shows that different treatments were found to have an impact on various plant growth parameters like plant height, number of leaves, and SPAD reading. The highest plant height (20.33 cm) was found in UV poly shade with cocopeat treatment and the lowest (14.66 cm) was observed in vermicompost treatment in both net house and open field conditions (Figure 1A). However, the net house with cocopeat treatment had the most leaves (13) while the plants treated with vermicompost and grown in UV poly sheds had the fewest leaves (9) (Figure 1B).

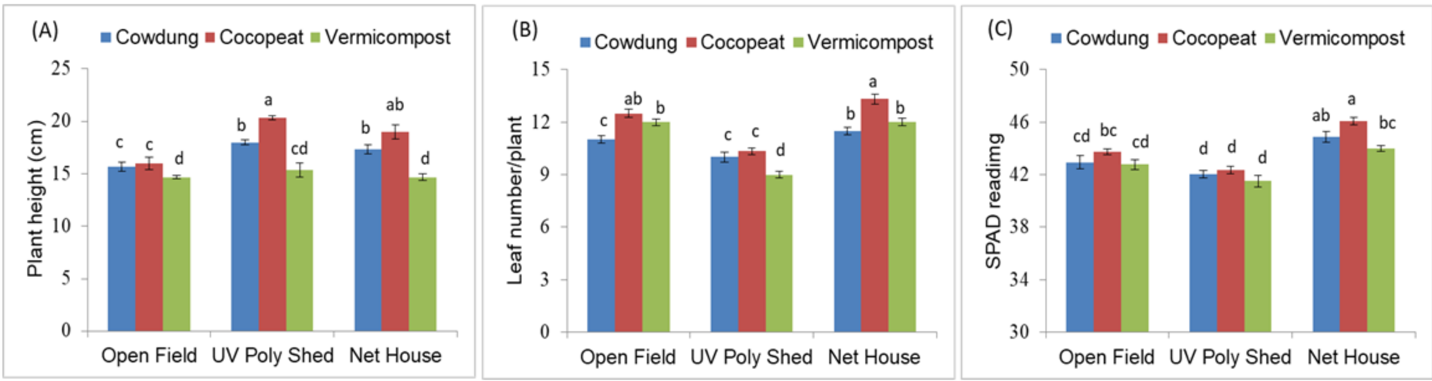

Figure 1. Average plant height (cm) (A), leaf number/plant (B), and leaf content of chlorophyll (SPAD reading) (C) of strawberry grown with different growing media under different shade houses. Mean±S.E (n=15). Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p<0.05$).

The plants grown in the net house with cocopeat-treated soil displayed the highest chlorophyll content (46.10), and the plants grown in the UV poly shade with vermicompost-treated soil displayed the lowest chlorophyll content (41.50) (Figure 1C). Lettuce plants grew taller and had more leaves when grown on cocopeat-based media, which provided adequate microclimate conditions in the root zone (Sarkar et al., 2021). Under cocopeat substrate, plant growth and development were accelerated, resulting in greater chlorophyll content in leaves. This could be owing to the availability of nutrients in cocopeat-based media. Sweet pepper growth parameters were much greater in peat-treated pots than in control pots (100% soil) (Rekani et al., 2016). Due to different temperatures, aeration, and soil moisture ability, different growing media can impact water and mineral uptake in the plant; thus, affect plant growth. An increase in enzymatic activity, microbial population, and plant growth hormones due to the use of sufficient increasing media may be responsible for an improvement in the physiochemical properties of the soil (Singh et al., 2011). It was also reported that the water holding capacity is better cocopeat compared to other growing media (Ozgumus, 1985). In our experiment, open field conditions and UV poly shed showed a significant decrease in leaf chlorophyll content. Due to decreased photosynthetic activity and increased rate of respiration, the higher temperature is likely to have a significant impact on limiting plant growth (Darnell & Hancock, 1996).

3.3. Effect of Different Shade Houses and Growing Media on Yield and Yield Traits

From the data presented in Figure 2, it is apparent that the differences among various treatments were found to be significant in respect of the number of flowers, fruits, individual fruit weight, and fruit yield per plant. The data reveals that the maximum number of flowers (19) and fruits (17 g) per plant was observed under in net house with cocopeat treatment. However, the lowest number of flowers (11) and fruits per plant (8 g) was recorded in a vermicompost treated plant grown under UV poly shed (Figures 2A & 2B). The highest fruit weight (18.03 g) was observed in plants treated with cocopeat grown in net houses, and the lowest fruit weight was observed in plants treated with vermicompost grown in all growing conditions i.e. open field, net house and UV poly shed (approximately 12 g) (Figure 2C).

There was a significant variation among shade houses and different growing media in response to fruit yield/plant. The highest fruit yield (307.11 g) was found in cocopeat treated plants grown in net house and the lowest yield (108 g) was found in vermicompost treated plants under UV poly shade condition (Figure 2D). Temperature above 25 °C can reduce fruit set of strawberry (Abdelrahman, 1984). In our experiment, air temperature in open field and UV poly shade was higher in January and February (flowering and fruiting stage) than the net houses condition, thus, affects the yield of strawberry. Strawberry fruit yield and quality can be affected by higher temperatures after bloom (Wang & Camp, 2000). High temperatures harm fruit set in strawberries, decreasing pollen viability and inhibiting pollen tube growth and pollen tube elongation (Ledesma & Sugiyama, 2005). In order to boost aeration resulting in the development of a better root system, various combinations of increasing media have been recorded (Verdonck & Demeyer, 2004) and result in higher yields (Albaho et al., 2009). Rostami et al. (2014), who also reported that when substrates composed of different growing media were used, the yield of strawberry significantly differed. The positive impact of cocopeat and its mixtures on improved root growth may lead to improved aeration, thereby creating a higher root system that may have facilitated shoot nutrient uptake leading to increased berry yield.

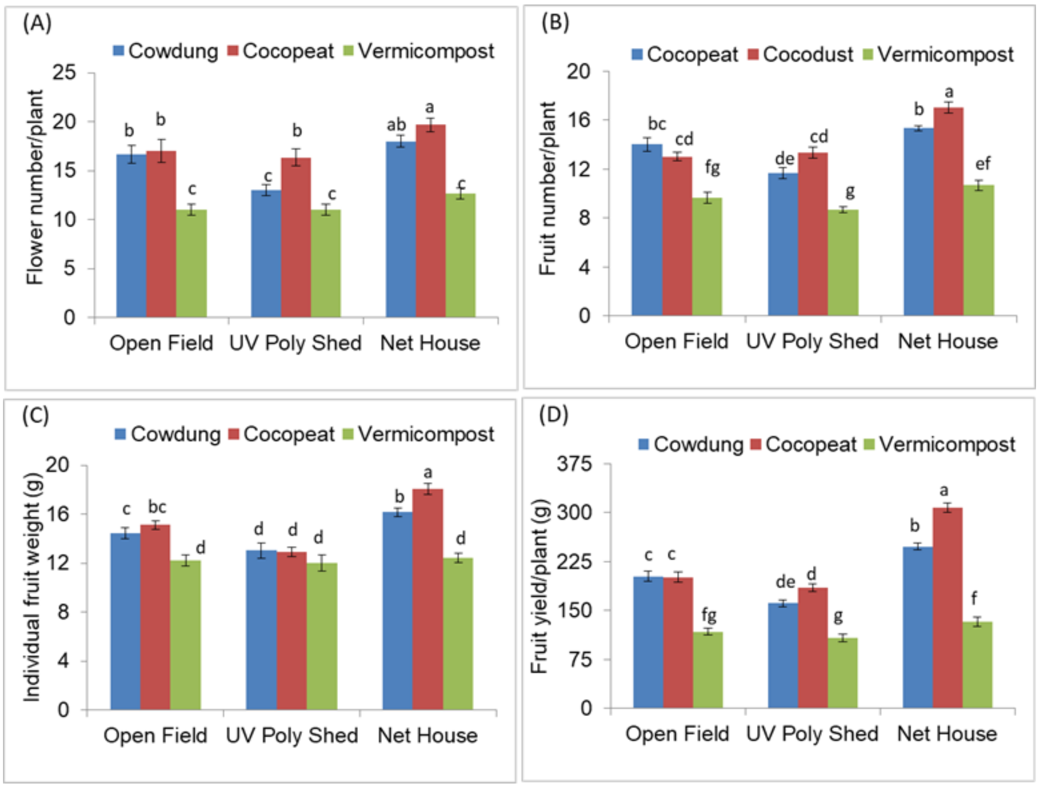

Figure 2. Average flower number/plant (A), fruit number/plant (B), individual fruit weight (g) (C), and fruit yield/plant (g) (D) of strawberry grown with different growing media under different shade houses. Mean±S.E (n=15). Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p<0.05$).

3.4. Effect of Different Shade Houses and Growing Media on Fruit Quality

The fruits of vermicompost-treated plants that are grown in net houses have the lowest ascorbic acid levels (35.83 mg 100 g^{-1}), while the fruits of cocopeat-treated plants that are grown in UV poly sheds and open fields have the highest levels (approximately 46 mg 100 g^{-1}) (Figure 3A). The quality of crops has also been improved by increasing the content of ascorbic acid in the fruit and, in particular, by increasing the sugar content (Wuzhong, 2002).

The higher TSS content was found in fruits grown with vermicompost treated soil and the lowest TSS content was found in fruits grown in cowdung treated soil in all growing environments (Figure 3B). The increased TSS and ascorbic acid content of the fruit could be attributed to better growing media, which aided in the uptake of NPK nutrients, including micronutrients that influence fruit quality traits (Lata et al., 2018). The fruits grown in UV poly shade with cowdung-treated soil had the lowest titrable acidity (0.37%), while those grown in the net house with cocopeat-treated fruit plants had the highest (0.62%) (Figure 3C). For strawberries to taste good, the acid content must be relatively high (Kader, 1991). However, the higher pH was found in UV poly shed with cowdung treated plant (3.69) and the lower pH was found in the net house with cocopeat and vermicompost treated plants (approximately 3.45) (Figure 3D). High fruit quality is associated with low pH (Davies et al., 1981). Loss of organic acids from ripe fruit tends to be largely due to respiration (Halinska & Frenkel, 1991).

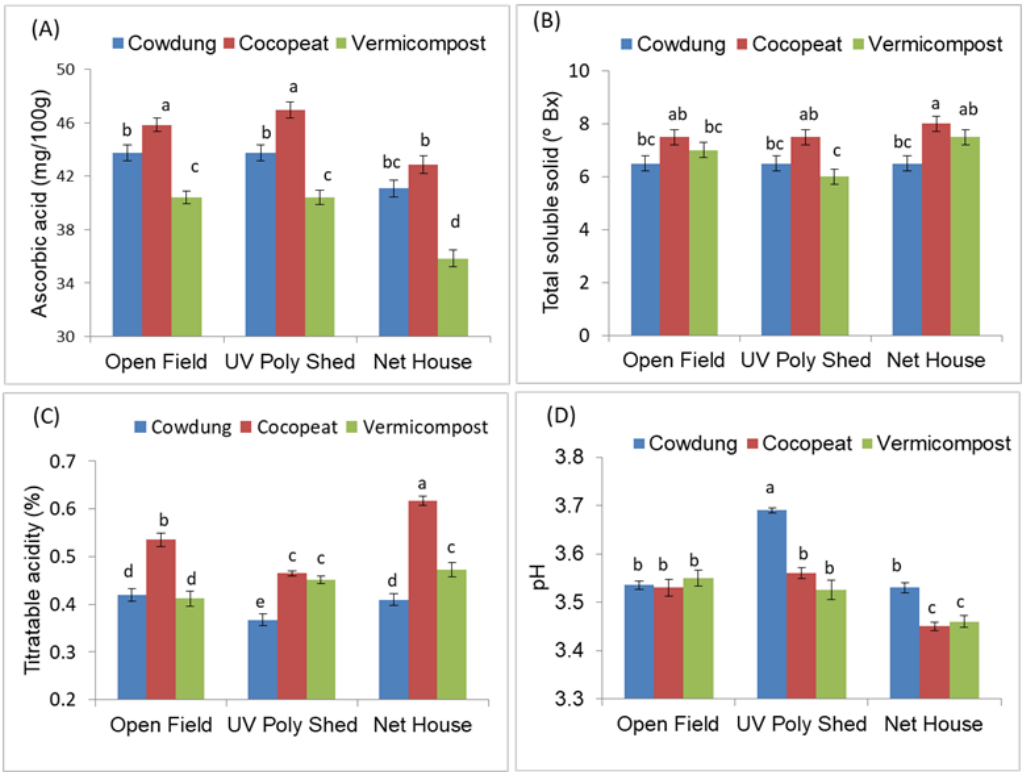

Figure 3. Average content of ascorbic acid (mg 100 g FW^{-1}) (A), total soluble solid (°Brix) (B), titratable acidity (%) (C), and pH (D) of strawberry grown with different growing media under different shade houses. Mean±S.E (n=15). Different letters mean significant differences between the treatments according to Duncan's multiple range test (p<0.05).

There was a significant difference in reducing sugar content in fruits grown with different growing media under different shade houses. The higher reducing sugar was found in cocopeat treated plants grown under the net house (8.75 mg g FW^{-1}), and the lower reducing sugar was found in the fruits grown in cowdung treated plants under open field conditions (8.1 mg g FW^{-1}) (Figure 4A). Likewise, Voca et al. (2009) showed that fruits grown under a tunnel were usually more reducing sugar than in open field cultivated fruits. The acid and sugar content of the fruit is related to its ripeness (Pérez et al., 1997), and higher sugar content is required for good strawberry flavor (Kader, 1991). The red-colored strawberry attracts buyers and hence serves as an effective fruit marketing criterion. The content of anthocyanin is influenced by many factors, such as temperature, light, food, hormones, etc (Karanjalker et al., 2018). In our result, the growing media and shade houses have significantly affected the total content of anthocyanin. As observed in Figure 4B, anthocyanin content decreased in strawberry fruit grown with cowdung under open field conditions (27.50 mg 100 g^{-1}). Meanwhile, anthocyanin content significantly increased in fruits grown in the net house with cocopeat treated soil (30.80 mg 100 g^{-1}). Increased content of anthocyanins was observed in fruits from plants grown on the peat-coconut substrate (Wysocki et al., 2017). This study showed the positive influence of shade on the total anthocyanin content of the strawberry. It was speculated that the content of anthocyanin could be related to ambient air temperature (Zoratti et al., 2015).

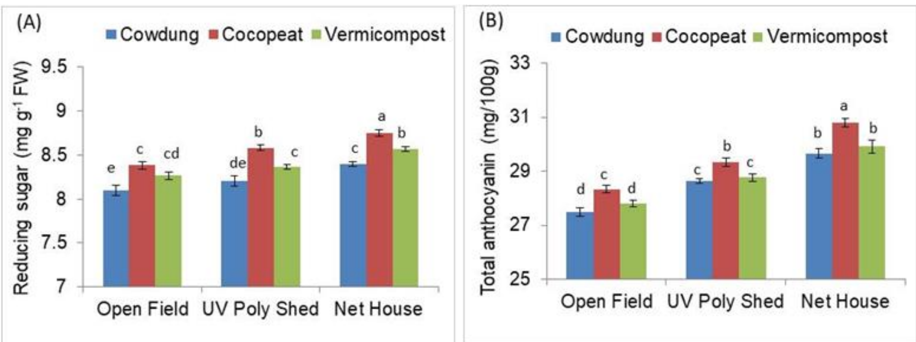

Figure 4. Average content of reducing sugar (mg g FW^{-1}) (A) and total anthocyanin (mg 100 g FW^{-1}) (B) of strawberry grown with different growing media under different shade houses. Mean±S.E (n=15). Different letters mean significant differences between the treatments according to Duncan's multiple range test (p<0.05).

3.5. ANOVA Analysis

The treatments had highly significant effect on yield and some quality traits i.e., reducing sugar, ascorbic acid and titratable acidity. However, growing media had no significant effect on pH and anthocyanin content (Table 3).

Table 3. Analysis of variance (F-value) for yield and different biochemical parameters of strawberry as affected by shed house, growing media and their interaction.

Parameters	Treatments	SS	df	MS	F
Average fruit weight (kg)	Shade house	34903.49	2	17451.74	5.75*
	Growing media	58100.55	2	29050.27	14.07**
	Shade house x growing media	103651.92	8	12956.49	58.68**
	Error	3973.81	14	283.84	
	Total	107625.73	26		
Total soluble solid (^{0}Brix)	Shade house	2.00	2	1.00	1.65^{NS}
	Growing media	6.50	2	3.25	7.80*
	Shade house x growing media	10.50	8	1.31	3.93*
	Error	6.00	14	.42	
	Total	16.50	26		
pH	Shade house	.03	2	.02	3.42*
	Growing media	.02	2	.01	1.93 ^{NS}
	Shade house x growing media	.09	8	.01	2.34 ^{NS}
	Error	.08	14	.01	
	Total	.17	26		
Titratable acidity	Shade house	.04	2	.02	3.65*
	Growing media	.05	2	.026	4.42*
	Shade house x growing media	.16	8	.020	10.13**
	Error	.03	14	.003	
	Total	.19	26		
Ascorbic acid	Shade house	241.13	2	120.56	10.62**
	Growing media	220.86	2	110.43	9.05**
	Shade house x growing media	486.46	8	60.81	40.47**
	Error	27.04	14	1.93	
	Total	513.51	26		
Reducing sugar	Shade house	.46	2	.23	8.42*
	Growing media	.54	2	.27	11.12**
	Shade house x growing media	1.02	8	.13	21.97**
	Error	.105	14	.007	
	Total	1.129	26		
Anthocyanin	Shade house	22.825	2	11.41	17.76**
	Growing media	3.575	2	1.78	1.23^{NS}
	Shade house x growing media	26.819	8	3.35	5.28*
	Error	11.424	14	.82	
	Total	38.243	26		

* $p<0.05$, ** $p<0.01$, NS: Not significant.

4. Conclusion

Strawberry plants responded better to the cocopeat-based growing medium than to the other growing media used (cowdung and vermicompost) across all growing shade features, while net house proved superior for reproductive growth and quality traits. The number of flowers, fruit, individual fruit weight, and fruit output of strawberry plants did not improve significantly when using vermicompost-based growing media. Based on findings obtained from the study cocopeat growing media and net house shade may be advised to obtain better quality and yield for strawberry.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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