Effect of Different Organic Potting Media on the Growth, Yield and Quality of Strawberry (*Fragaria ananassa*) under Greenhouse Condition

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Abstract

The type and composition of potting media are the most influencing factors affecting the growth, fruit quality and yield of strawberry plants. The objective of this study was to evaluate the effects of various organic potting media compositions on the growth, yield and quality parameters of strawberries grown in a greenhouse. The experiment was laid out using randomized complete block design with five treatments consisting of three replications in each treatment. The treatments were compost mix, vermi-compost mix, leaf mold mix, biochar mix and the control (top soil and sand). The growth of the plants grown in different organic potting mixes was measured at 15 days, 30 days, 45 days, 60 days and 75 days after transplantation. Plants grown in leaf mold mix was found to perform well in growth compare to other treatments. Fruit yield parameters such as the number of fruits were highest with vermi-compost mix. The compost mixes also produced best fruit quality attributes like their total soluble solids with 10.84 ^{O}Brix. The control produced the lowest results for growth, yield and quality followed by biochar mix media. For strawberry production in greenhouse compost mix media is found to have maximum overall effect among other treatments.

Keywords: Biochar, Compost, Leaf mold, Strawberry, Vermi-compost

Introduction

Strawberries (*Fragaria ananassa*) are a fruit species of the genus *Fragaria* that is cultivated worldwide for fresh fruit and is known for their sweet fragrance, juicy texture and attractive color (Potter et al., 2007). China is the world's leading strawberry producer with 3,801,865 tons followed by the United States of America with 1,420,570 tons annually (Appelmann, Fernando, Giraldo, & Vargas, 2020). Strawberry fruit has a high nutrient content and health benefits (Wallace et al., 2019) and is known as an excellent source of vitamin C, and a good source of folate, potassium and manganese (Daugaard, 2006). In Bhutan, strawberries have been grown on a commercial scale since the release, between 2006 and 2014, of Chandler, Sweet Charlie and Camarosa by the National Centre for Organic Agriculture (NCOA), Yusipang (Ngawang, 2017).

Studies have been conducted to study the factors that affect the productivity and quality of strawberry fruits. Factors like diverse growing environments and improved production techniques are found to affect the growth, yield and quality of fruits (Ahmad, Ahmad, Sarwar, Shafi, & Shehzad, 2013). Strawberry yield can also be improved by growing in a protected environment using suitable potting media (Ford et al., 2020). Potting media substrates are the most important factor for the quality production of fruits in horticulture (Burnett et al., 2016).

Organic substrates have been widely considered for their potential use in agriculture but little attention has been paid to the use of organic substrates in potting media. It is known for its low cost, high nutrient contribution and immunity against soil- borne diseases. However, in Bhutan, there is no specific substrate recommended as potting media for strawberry cultivation, nor it has been studied. Therefore, this study will evaluate the growth, fruit quality and yield performances of Praratchatan No. 80 of Thailand strawberry variety in response to organic different potting media substrates. The findings from this study will be important in developing suitable potting media for providing low-cost, high-efficiency potting media for strawberry production in Bhutan.

Methods and Materials

Study Area

The experiment was conducted at the mini-farm of the College of Natural Resources (CNR), Lobesa (Figure 1) between 28th January and 15th April, 2021; 75 days, in a greenhouse. The area experiences hot summers and cool dry winters. The relative humidity and maximum and minimum temperatures in the greenhouse during the experiment were monitored.

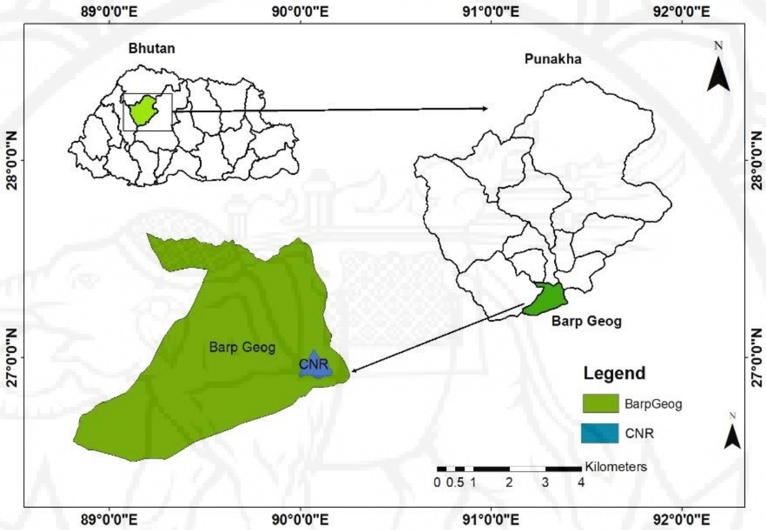

Figure 1 CNR mini-farm under Punakha Dzongkhag, Bhutan

Materials

The materials required for the experiment were a greenhouse, plastic poly pots, strawberry seedlings, wood chips biochar, compost, vermi-compost, leaf mold, topsoil, sand and field preparation tools. An imported strawberry variety, Praratchatan No. 80 was used and offsets of plants were brought from the Integrated farm of the CNR, Lobesa. A total of five treatments, listed in Table 1, were used. Biochar was prepared at CNR using softwood chips.

Table 1 Composition of different treatments

Treatment	Composition
T_1	Compost (Top soil + Compost + Sand) 25:50:25
T_2	Vermi-compost (Top soil+ Vermi-Compost + Sand) 25:50:25
T_3	Leaf mold (Top soil + Leaf mold + Sand) 25:50+25
T_4	Biochar (Wooden chips biochar + Top soil + Leaf mold) 25:50+25
T_5	Control (Top Soil + Sand) 75:25

Biochar Preparation

The softwood offcuts were collected from the Druk integrated wood complex, Lobesa. The materials were burned in an airtight drum prototype, developed by Bajo, Agriculture Research and Development Centre. The materials were burned for five hours using a slow pyrolysis process (Novak et al., 2009) and the biochar that was produced was stored in a plastic bag to prevent the loss of carbon. The biochar was then ground to about 20-30 mm (diameter) of pebble size for media preparation.

Experimental Design

The experimental design was a Randomized Complete Block Design (RCBD). One-year-old healthy stolons of the selected variety (Praratchatan No. 80) were planted in poly pots (4 inches: 4.33" x 3.93") containing the potting media of different treatments. Each treatment was replicated three times with 10 plants for each replication, with a total of 150 strawberry plants. The strawberry plants were kept on raised wooden platforms inside the greenhouse and the transplanted plants were kept in the greenhouse with all the management practices like irrigation and weeding carried out in the greenhouse.

Sampling Method

Five plants from each replication were randomly selected by using a random table. The plants were tagged for the data collection on growth and yield parameter throughout the experiment.

Data Collection

The plant growth parameters such as crown diameter, length and width (cm) of the leaves from randomly selected plants were measured 5 times in each replication at 14-day intervals. The heights of the plants were measured, in centimeters, from the crown level to the apex of the primary leaves and the result was expressed as the average height of the samples. Yield parameters such as the number of fruits per plant, fruit weight and fruit diameter, were recorded. Fruit quality parameters of the Total Soluble Solid (TSS) and color were assessed.

Soil Sampling and Analysis

Soil sampling and analysis were done twice; before the start of the experiment and after the harvest. After collecting the entire soil and treatment samples, the collected soil samples were air-dried for 24 hours at room temperature then labeled, dried, crushed and sieved through a .05 mm sieve. Macro-nutrients such as nitrogen, phosphorus, potassium, and soil organic carbon were analyzed both before the commencement of the experiment and again at the end of the experiment. The Bray II extraction method was used to test the available phosphorus while available potassium was determined in ammonium acetate using the flame photometer method, using reagents like ethyl alcohol 40%, absolute alcohol and ammonium acetate solution. The soil pH was also analyzed. The loss on ignition method was used to determine the available nitrogen and organic carbon.

Data Analysis

A Shapiro-Wilk test was run to check the normality of the data. Inferential data analysis was carried out using Microsoft Excel in Office 2019 and the statistical software R version 2.13.1. The data that was collected for measuring the quantitative variables such as the growth and yield of the strawberry plants were statistically analyzed by using analysis of variance (ANOVA). Bonferroni *post hoc* tests were carried out to determine the level of significance between the means of treatments. A probability level of $p<0.05$ was considered significant.

Results and Discussion

Climate Conditions

The climate conditions maintained in the greenhouse for the entire study period are shown in Figure 2. The maximum temperature inside the greenhouse of 33.26°C was recorded in April and the minimum of 6.35°C was recorded in the first week of January, as shown in Figure 2 (A). The ideal temperature range for strawberries grown in a greenhouse is 18°C – 24°C (Kumar & Ahad, 2013).

Night temperatures are also important for strawberry growth and yield and optimally should be between 10°C and 12°C. Higher night temperatures result in lower quality due to respiration from the fruit (Kuack, 2017). However, the night temperature in the study, after the fifth week of transplantation, started to increase to between 13°C and 16^{O}C. These temperatures affect the texture of the fruit, with a low sugar content affecting the sweetness, with a high level of acidity of strawberry fruit, if the night temperature is outside the optimum range of 10°C to 12°C). For optimal growth and better yields of greenhouse-grown strawberries, relative humidity (RH) of 65% to 75% is considered optimum (Lieten, 2002). The maximum RH recorded was 91.9% and the minimum was 42% as shown in Figure 2 (C).

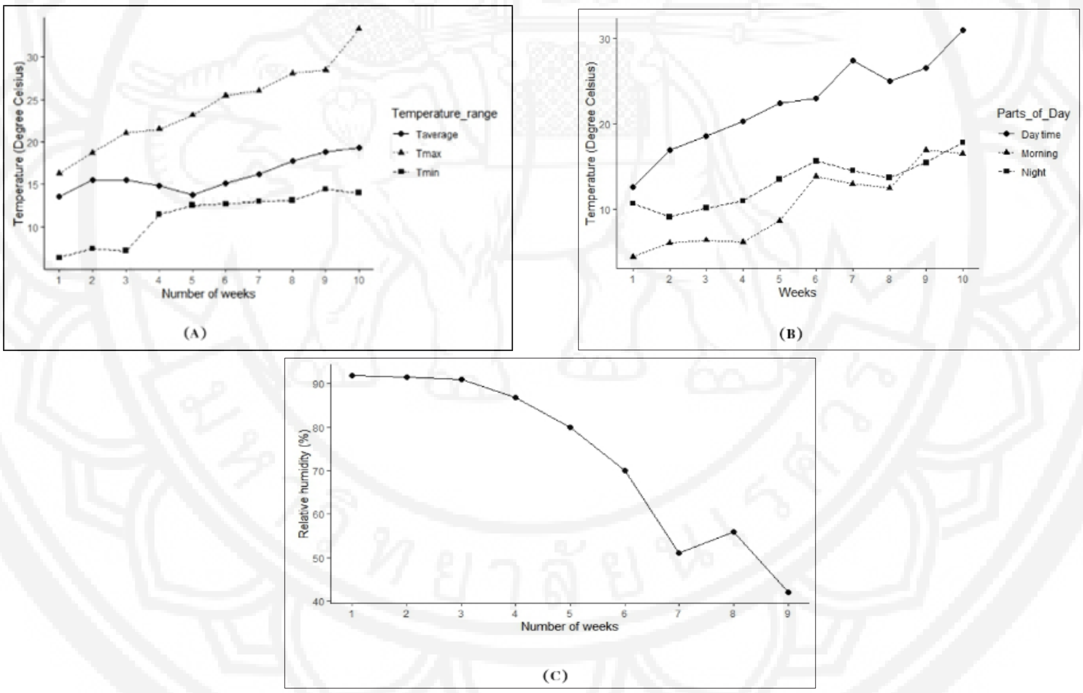

Figure 2 (**A**) Maximum, Minimum and Average temperature; (**B**) The temperature during the day, night and morning; (**C**) Relative humidity in a greenhouse

Nutrient Composition Analysis of Potting Media Substrates

The nutrient analysis of compost mix, vermi-compost, leaf mold mix, softwood biochar mix and control are shown in Table 2. The lowest pH of 5.1 was found in the control, showing that it is acidic, and in the leaf mold mix which also had the highest nitrogen (N) (1.98%) content. The humic nature of leaf mold media provides good moisture retention for the strawberry seedlings to grow. The vermi-compost mix contained the highest phosphorus (P) with a pH of 6.8. Keeping the pH value near 6.5 helps in maintaining the optimum level of P

(Merino & Tellez, 2014). The softwood biochar mix is rich in potassium (K) (2004 ppm) compared to other treatments. And, it has the highest potential of hydrogen (pH) of 8.1 showing alkaline nature. Potassium availability of soil is generally high above the pH of 6.0 (Khadka, Lamichhane, & Thapa, 2016). Control has the least nutrient content among other treatments studied.

Table 2 Pre-nutrient content of the different potting media

Treatment	Avail. K (ppm)	Avail. P (mg/kg)	N (%)	SOC (%)	SOM (%)	pH (H_2O)
Compost	1426	0.36	1.59	18.53	31.88	7.6
Vermi-compost	1248	0.136	1.83	21.37	36.76	6.8
Leaf mold	408	.046	1.98	23.02	59.93	6.2
Biochar	2004	.073	1.74	34.84	39.60	6.1
Control	500	.04	1.13	13.15	22.63	5.1

SOC: Soil Organic Carbon and SOM: Soil Organic matter

The potting media soil analysis that was conducted after the harvesting of the fruit at 75 days after transplantation (DAT) showed that there was a significant change in soil nutrient composition (Table 3). There was a slight increase in the pH value of all the treatments. An increase in pH has also been reported in other long-period studies with biochar and organic manure application (Chan, Downie, Joseph, Meszaros, & Van, 2008; Yuan, Xu, Wang, & Li, 2011). However, the nutrient content of all the treatments decreased showing that the plants used these nutrients for growth and development. The reduction in NPK is also associated with plant agronomic practices such as weeding and irrigation that lead to leaching and volatilization.

Table 3 Post-nutrient content of the different potting media

Treatment	Avail. K (ppm)	Avail. P (Abs)	N (%)	SOC (%)	SOM (%)	pH (H_2O)
Compost	91.7	0.133	1.15	13.47	23.18	7.61
Vermi-compost	128	0.12	0.84	9.85	16.95	6.33
Leaf mold	38.4	0.072	0.57	6.66	11.45	6.75
Biochar	27.3	.09	1.70	19.83	34.11	5.84
Control	13.3	.066	1.57	18.30	31.47	5.71

SOC: Soil Organic Carbon and SOM: Soil Organic matter

Growth Parameters

Crown Diameter

Significant effects of the different potting media on the crown diameter of each strawberry plant were observed. There was no significant difference among the means of all treatments during its early growth stages of 15 DAT and 30 DAT, but significant differences were recorded at 45 DAT, 60 DAT and 75 DAT at which time the thickest crowns were measured with an average mean per pot of M = 18.27 mm, M = 22.72 mm and M = 26.64 mm in leaf mold mix media (Table 4). The leaf mold mix medium showed a maximum stem diameter that agreed with Eshghi, Tafazoli, and Yavari (2008) who also observed the thickest stems in leaf mold medium.

The results highlighted the maximum increase in crown diameter which was also in agreement with Bakshi et al. (2018) who found significant results for strawberry plants growing in media containing leaf mold manure. The control had the lowest crown diameter (M = 11.10 mm, M = 16.05 mm, M = 20.26 mm and M = 24.83 mm). As the plants reached the maturity stage, the diameter of the strawberry crowns ceases to grow.

Table 4 Crown diameter mean and standard deviation in different potting media

	Days after transplantation				
Treatment	**15**	**30**	**45**	**60**	**75**
Compost	4.97±0.46[a]	11.58±1.52[a]	16.23±1.25[b]	21.33±1.43[abc]	25.38±1.52[ab]
Vermi-compost	5.14±0.63[a]	11.80±1.38[a]	17.57±1.99[ab]	21.81±1.17[ab]	25.82±1.63[ab]
Leaf mold	4.90±0.59[a]	12.83±1.36[a]	18.27±1.45[a]	22.72±1.28[a]	26.64±1.27[a]
Biochar	5.04±0.58[a]	11.89±2.41[a]	16.43±1.18[b]	21.05±1.47[bc]	25.18±1.69[ab]
Control	5.16±0.57[a]	11.10±1.29[a]	16.05±1.08[b]	20.26±1.59[c]	24.83±1.54[b]
***F*-test**	ns	ns	**	**	*
CV (%)	11.41	11.54	8.58	6.44	6.08

**= significantly different (p < .05), ** = significantly different (p < .01), ns= not significant. The different lowercase alphabet given above shows a significant difference at (p < .05) between treatments on BOnfErrOni All-Pairwise Comparisons Test. CV: Coefficient of variation.*

Plant Height

The effect of potting media on the plant height was not significant during the early 15 DAT stage, $F_{(4, 70)}$ = 0.209, p = .933. However, the differences in the height of the established plants in the different potting media combinations were significant after 30 DAT. The plants grown in the leaf mold mix media were the tallest with a mean rank of M = 13.25. At 30 DAT, the mean rank of M = 11.75 was recorded for the plants in the vermi-compost media, M = 11.22 in the compost, M = 10.2 in softwood biochar, and M = 9.25 in the control. Similar findings were reported by Dubsky and Sramek (2008) who found maximum plant height in leaf mold substrate.

The maximum increase in plant height was attained in leaf mold mix media which might be due to the higher nitrogen content of 1.98% than in the other treatments. Nitrogen is most important for plant growth. Neuweiler (2001) found a positive response of strawberry plant vegetative development to increased nitrogen fertilizer application. The shortest plant was recorded in the control plants with M = 9.52 cm at 30 DAT, M = 10.12 cm at 45 DAT, M = 12.11 cm at 60 DAT, and M = 13.36 cm at 75 DAT.

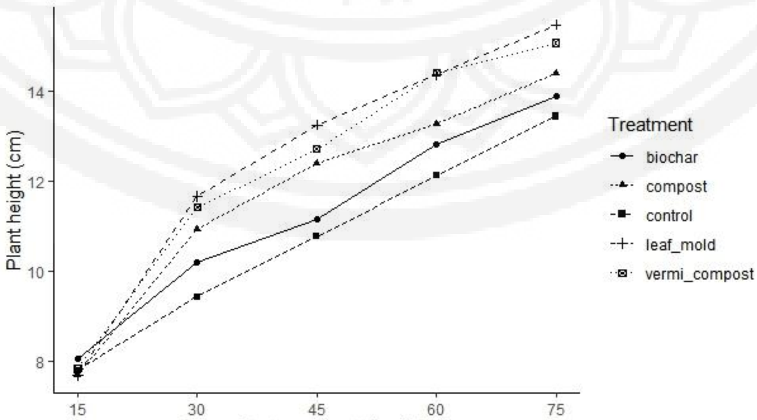

Figure 3 Effect of different potting media on the height of strawberry

Yield and Quality Parameters

Number of Fruits per Plant

There were statistically significant differences for the fruit numbers in the different treatments $F_{(4, 70)}$ = 6.029, p <0.001) with a mean rank of M = 7.86/plant in the vermi-compost mix media followed by compost mix with M = 7.73/plant, leaf mold mix with M = 7.06/plant, M = 6.53/plant in biochar and M = 6.33/plant in control as least. The vermi-compost mix enhanced potting media quality and health parameters of strawberry plants. The vermi-compost mixes contain significant amounts of essential nutrients like potassium and nitrogen. During the process of fruit ripening, fruits represent a sink for these essential elements. The pairwise comparisons showed no significant difference between the compost, vermi-compost and leaf mold media, whereas there was a significant difference between other treatments.

Table 5 Effect of different potting media on the number of fruits per plant

Treatment	Number of fruits
Compost	7.73±1.62[a]
Vermi-compost	7.86±1.18[a]
Leaf mold	7.06±1.09[ab]
Biochar	6.53±0.99[b]
Control	6.33±0.97[b]
***F*-test**	**
CV (%)	17.18

*** = significantly different (p < .01). The different lowercase alphabet given above shows significant difference at (p < .05) between treatments on BOnfErrOni All-Pairwise Comparisons Test of fruits for Treatment. CV: Coefficient of variation.*

Fruit Diameter

High significant variation (p<.05) was observed among the means of the treatments on the fruit $F_{(4, 70)}$ = 12.392, p < 0.001). The highest fruit diameter was obtained in compost mix potting media (M = 30.05 mm) followed by vermi-compost mix media (M = 29.08 mm) and the least in the control (M = 25.19 mm). The compost and vermi-compost-based organic potting media enhanced the fruit diameter and improved the quality of the fruit, as was also found by Khalid, Khan, Hafiz, Qureshi, and Qureshi (2013). Compost mix media and vermi- compost mix contain a relatively greater amount of nutrients and mineral sources. The nitrogen level in the vermi- compost mix media was 1.83%, soil organic carbon (21.37%), soil organic matter (36.76%), phosphorus (0.136 mg/kg), and potassium (1248 ppm). The optimum pH of the compost mix (7.6) and vermi- compost mix (6.8) favors better fruit yields as it regulates the plant nutrient availability by controlling the chemical forms of the different nutrients.

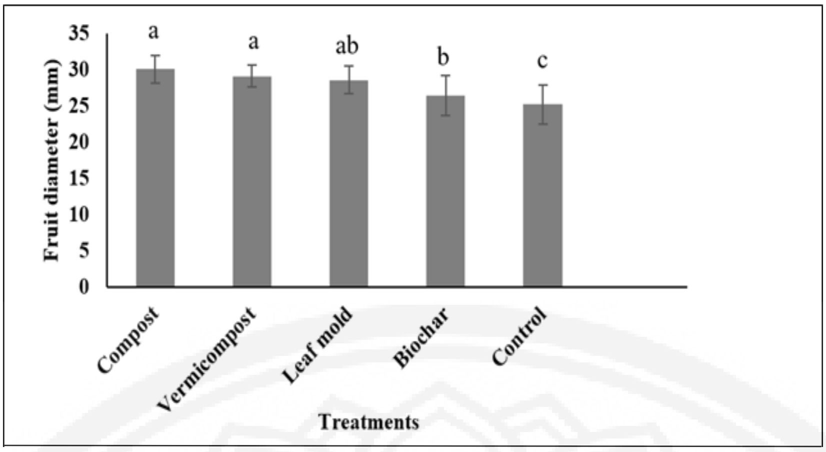

Figure 4 Effect of different potting media on the fruit diameter of strawberry

The different lowercase alphabet given above shows a significant difference at ($p < .05$) between treatments on BOnfErrOni All-Pairwise Comparisons Test.

Fruit Weight

There were no significant pairwise differences ($p < .05$) among the means of treatments on fruit weight, $F_{(4, 70)} = 2.428$, $p = .056$). The highest fruit weight was obtained in compost mix potting media with a mean rank of $M = 14.52$ g followed by vermi-compost mix media with $M = 13.26$ g and least in control with $M = 11.25$ g as shown in figure 5. Compost potting media improved the water retention capacity of potted soil and improvement of crop yield. Aracnon et al. (2004) showed that the application of vermi-composts improved nitrogen and phosphorus uptake in potted plants and increased fruit weight.

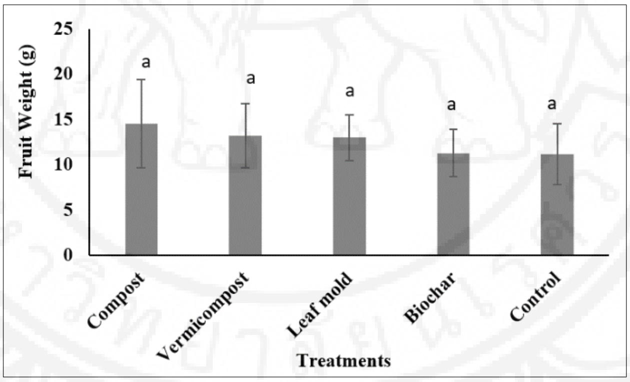

Figure 5 Effect of different potting media on the fruit weight

Total Soluble Solids of Fruits (TSS)

The TSS of the fruits in this study were analyzed using a refractometer. TSS values in this study were similar to those found by Kumar, Mishra, and Singh (2015) in the growing condition of Narendra Deva University of Agriculture and Technology (10.75 ^{O}Brix). Regarding the culture system used, the highest TSS was found in fruits produced in compost mix potting media (11.52 ^{O}Brix) followed by vermi-compost mix media with a mean of 10.84 ^{O}Brix. Compost mix has the maximum phosphorus content (0.36 mg/kg) as shown in figure 3.6 and Phosphorus application was found to help in enhancing the TSS of fruits (Aracnon et al. 2004). TSS content of the strawberries was found to be positively correlated with phosphorus content in ripening strawberry fruits (Cao, Dai, & Guan, 2015). Control has the lowest TSS value of 8.97 ^{O}Brix. Brackmann et al. (2011), assessing the quality of strawberry cultivars and clones grown in topsoil, had a mean 7.12°Brix, which was lower than the results in this study. It was noted that organically grown strawberries had a higher soluble solids content, but a lower content of ascorbic acid compared with conventionally grown strawberries (Kahu, Kikas, & Klass, 2010).

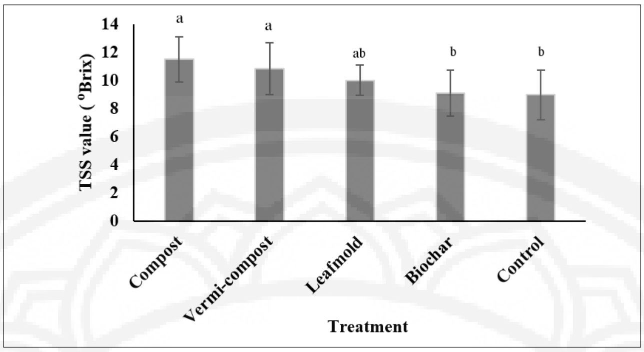

Figure 6 Effect of different potting media on the TSS of strawberry

(The different lowercase alphabet given above shows significant difference at ($p < .05$) between treatments on BOnfErrOni All-Pairwise Comparisons Test.)

Fruit Color

The effect of different treatments on the fruit color of the strawberries is shown in Figure 7. The grading of fruit color is studied using a horticulture color grading chart, Fan 1 (Red group) that categorizes the pigments to grade A, B and C. Grade A signifies the best color of the fruit followed by B and C as low. Results showed that the best fruit color was obtained from vermi- compost mix media with the maximum number of fruits with grade A. The color obtained from compost mix media was good as well. However, the control and softwood chips biochar media impart poor color in fruits. Abiotic factors like light and temperature affect the color of fruits. High temperature causes a decrease in the synthesis of anthocyanins in the reproductive organs of fruits (Folta & Pillet, 2015). These findings suggest that the activity of the fruits depends not only on the potting media but also on the weather conditions.

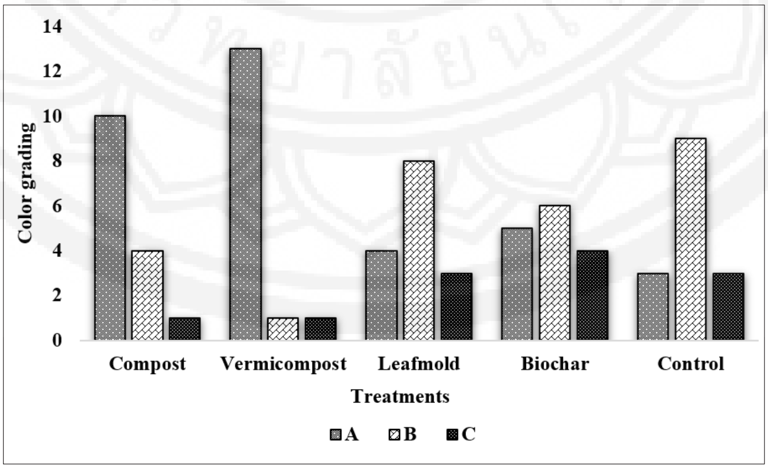

Figure 7 Fruit color graded as A, B and C

Conclusion and Suggestions

When the growth and vigor of the strawberry plants were evaluated using different organic potting media, leaf mold mix media showed higher growth in terms of plant height, crown diameter, leaf length and width. The fruit quality and yield were relatively closer to compost mix and vermi-compost media though a little less than the other two media. The number of fruits obtained, fruit weight, fruit diameter, color, and TSS were obtained best from the compost mix media followed by vermi-compost mix media. However, all these three media; compost, vermi-compost and leaf-mold, were found to be suitable potting media for strawberry production in the greenhouse unlike softwood biochar and control media. To achieve the best performance of strawberry plants, issues related to potting media types, and climatic conditions must also be taken into consideration. This study shows that using potting media from organic sources not only improves the quality of the fruit but is also a healthy practice in strawberry production.

The results obtained in this research indicated that leaf mold mix potting media, compost mix and vermi-compost mix media can be recommended as a standard potting media to produce strawberries in a greenhouse. These treatments can also be studied for different crops that can be grown in poly pots to further confirm the efficacy of the potting mixtures for growth and yield. According to the results obtained in this experiment, the use of softwood biochar mix as potting media was found to have less effect on the growth and yield of the strawberry plants and fruit while, activated biochar and biochar of other substrates such as rice husk as potting media may also be effective for strawberry production. The less effective biochar could be due to its size of about 20 mm - 30 mm pebble size used in the study. Future researchers may grind the softwood biochar into pieces of about 0.4 mm in diameter and study its effect. Moreover, researchers may continue this research beyond 75 DAT and study stolon production and the number of stolons in plants.

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