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Combined Effect of Rice Husk Charcoal with Peatmoss or Cocopeat on Increasing Seedling Growth of Two Introduced Strawberry Cultivars

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ABSTRACT

The introduction of strawberry cultivars from subtropical to tropical regions is one approach to improving strawberry fruit quality in tropical environments. However, careful attention must be paid to cultivation technology, from propagation through to production, particularly when employing hydroponic systems. Within this context, the selection of an appropriate planting medium for strawberry growth under an ebb-and-flow hydroponic system becomes crucial, as it directly influences the production of robust, high-quality seedlings. The aim of this study was to determine the most suitable planting medium for seedling growth in two Japanese cultivars, 'Berry Pop Sakura' and 'Berry Pop Haruhi', under ebb-and-flow hydroponics. Seedlings of both cultivars were grown in seven different media: peatmoss, cocopeat, rice husk charcoal, peatmoss + cocopeat (1:1 v/v), peatmoss + rice husk charcoal (1:1 v/v), and cocopeat + rice husk charcoal (1:1 v/v), all within an ebb-and-flow hydroponic system. The results demonstrated that combined growing media were more effective than single-component media in promoting seedling growth in both cultivars. Among the mixtures tested, the combinations of peatmoss + rice husk charcoal and cocopeat + rice husk charcoal were more effective than the peatmoss + cocopeat mixture in improving several key growth parameters, including plant height, fresh plant weight, number of leaves, and number of roots in both cultivars. We conclude that rice husk charcoal, when used in combination with either peatmoss or cocopeat, serves as an effective component of a seedling growing medium for strawberries cultivated in tropical regions under an ebb-and-flow hydroponic system.

Introduction

Strawberries (*Fragaria* × *ananassa* Duch.) are among the horticultural crops widely developed throughout the country and are in great demand because of the nutritional content of the fruit. Strawberries contain bioactive compounds due to their elevated concentrations of vitamin C, folate, and phenolic metabolites (Bader et al., 2022; Farida et al., 2023), which are used for improving human health and preventing disease (Afrin et al., 2016). Basu et al. (2016) report that consuming strawberries reduces the risk of type 2 diabetes by improving blood plasma antioxidant status. Due to their beneficial functions for human health, strawberries are widely cultivated in several countries, including Indonesia. In Indonesia, strawberries are mostly

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cultivated in high-altitude regions with low temperatures.

Strawberry cultivation in Indonesia faces two main challenges, namely low production and issues of fruit quality, such as excessive sourness. One alternative to address these problems is the introduction of new strawberry cultivars from other regions, such as Japan. Cultivar introduction is feasible because existing cultivars still cannot optimally fulfill consumer preferences, both in terms of taste and fruit size. Introducing a new strawberry cultivar is therefore a promising option to meet consumer needs while also contributing to product variation. The presence of new, higher-quality cultivars will greatly influence yield productivity.

However, to successfully develop these introduced strawberry cultivars, it is necessary to conduct several studies on their growth performance, beginning from seedling production through to cultivation. One hydroponic method suitable for this purpose is the ebb and flow system, which operates by flooding the growing medium for a specific period and then draining or flowing the water back into the reservoir for reuse in the next cycle (Berry and Knight, 1997). In the ebb and flow system, selecting the appropriate aggregate for a growing medium is crucial for plant growth and for mediating nutrient solutions.

Several studies have reported the impact of various hydroponic growing media on plant growth, yield, water-use efficiency, and evapotranspiration, as well as on the effects of EC and pH on leaf coloration and plant height (Mahjoor et al., 2016; Wortman, 2015; Niu et al., 2015). Sahoo et al. (2024) stated that strawberry plants grown in a soilless hydroponic method supplemented with an appropriate nutrient-solution concentration could effectively replace the conventional soil-based cultivation method. Optimizing hydroponic substrates is therefore critical for the adaptation of introduced cultivars under tropical conditions.

Organic materials such as cocopeat and rice husk charcoal hold promise as potential alternative composite substrates for hydroponics because they help maintain aeration balance. Utilizing organic materials—particularly those derived from abundant and cost-effective waste—offers a viable option for alternative growing media that are otherwise difficult to replace. Agustin et al. (2014) found that rice husk charcoal decomposes easily and has high carbon content and high absorption capacity due to its large pore size, while cocopeat can impede water drainage, leading to increased water availability (Istomo and Valentino, 2012). In addition to husk charcoal and cocopeat, peatmoss is widely used as a growing medium. Peatmoss results from the natural decomposition of organic material in cold and wet environments.

Previous studies have extensively reported the use of single media in hydroponic cultivation techniques for crops such as chili peppers (Jusoh et al., 2025; Alzrog et al., 2021), strawberries (Sharif et al., 2025; Woznicki et al., 2019), and several other horticultural plants. However, there are still few reports on the use of media combinations for strawberry seedlings in an ebb and flow hydroponic system. Therefore, this study was conducted to evaluate the effect of mixed organic media on the growth of seedlings of two introduced strawberry cultivars under an ebb and flow hydroponic system.

Materials and Methods

Preparation of plant material

A split-plot design with two factors, namely cultivar and growing medium, was used in this experiment. Seeds of two strawberry cultivars, 'Berry Pop Haruhi' (19FAG-2; Miyoshi & Co., Ltd., Tokyo, Japan) and 'Berry Pop Sakura' (19FAG-1; Miyoshi & Co., Ltd., Tokyo, Japan), were sown in plug trays filled with a combination of commercial coir cocopeat and rice husk charcoal (1:1 v/v) (JM Tani, Bandung, Indonesia) as the initial growing medium. After producing 4–5 true leaves, the seedlings were transplanted and cultivated in seven different growing media: peatmoss (A), cocopeat (B), rice husk charcoal (C), peatmoss + cocopeat (1:1 v/v) (AB), peatmoss + rice husk charcoal (1:1 v/v) (AC), and cocopeat + rice husk charcoal (1:1 v/v) (BC), all under an ebb and flow hydroponic system. The plants were irrigated twice per day for a total of 10 min d^{-1}. The seedlings were fertilized with a commercial nutrient solution (Table 1) with an EC level of 0.5–0.6 dS m^{-1}.

Table 1. Nutrient composition for strawberry seedling fertilizer.

Components	Amount g L^{-1}
$Ca(NO_3).4H_2O$ (Ca = 18%, NO_3 = 11,8 %)	1000
KNO_3 (K = 38%, NO_3 = 13%)	300
KH_2PO_4 (K = 28,7%, P = 22,8%)	300
$MgSO_4$ (Mg = 9,7%, S = 13%)	600
K_2SO_4 (K = 44,8%, S18,4%)	50
Fe EDDHA (Fe = 6 %)	10
$CuSO_4$	1
$MnSO_4$	5
$ZnSO_4$	1
H_3BO_3	5

The transplanted seedlings were grown in an indoor cultivation room at a daily temperature of 22±2 ºC and a humidity of 64±2%, supplemented by artificial light for 12 h d^{-1} with the PPFD of 20-30 µmol m^{-2} s^{-1}.

Data mining and analysis

The seedling growth of the two strawberry cultivars was measured. Several observations were made to analyze the effect of growing media on seedling growth, particularly in relation to vegetative organs, including both the upper part (leaves) and the lower part (roots), at 35 days after transplanting (DAT). The number of plants observed consisted of three plants per treatment, with three replications. Plant height was assessed using a ruler, measuring from the base of the stem to the tip of the highest point of the strawberry plant; the number of leaves was counted for all expanded leaves present on the plant; crown height was measured using a ruler from the stem collar to the point of crown growth of the strawberry plant; fresh weight was determined by weighing the entire plant, including both leaves and roots; root length was measured from the base of the stem to the tip of the longest root; and the number of roots was counted for all roots emerging from the plant. All collected data were subjected to analysis of variance, followed by Tukey's test at a significance level of α = 0.05 using Minitab. Furthermore, a multivariate analysis in the form of correlation analysis was performed using RStudio version 2023.06.2+561.

Results

Plant height

Based on the presented data, it can be inferred that the growth response of the two strawberry cultivars differs according to the type of growing medium used. In 'Berry Pop Sakura', seedlings grown in cocopeat + rice husk charcoal (BC) produced the tallest plant height, although this value was not significantly different from most other treatments except for seedlings grown in peatmoss + cocopeat (AB). On the other hand, the tallest plant height in 'Berry Pop Haruhi' resulted from the peatmoss + rice husk charcoal (AC) medium, but this was not significantly different from plants grown in cocopeat + rice husk charcoal (BC) (Fig. 1A).

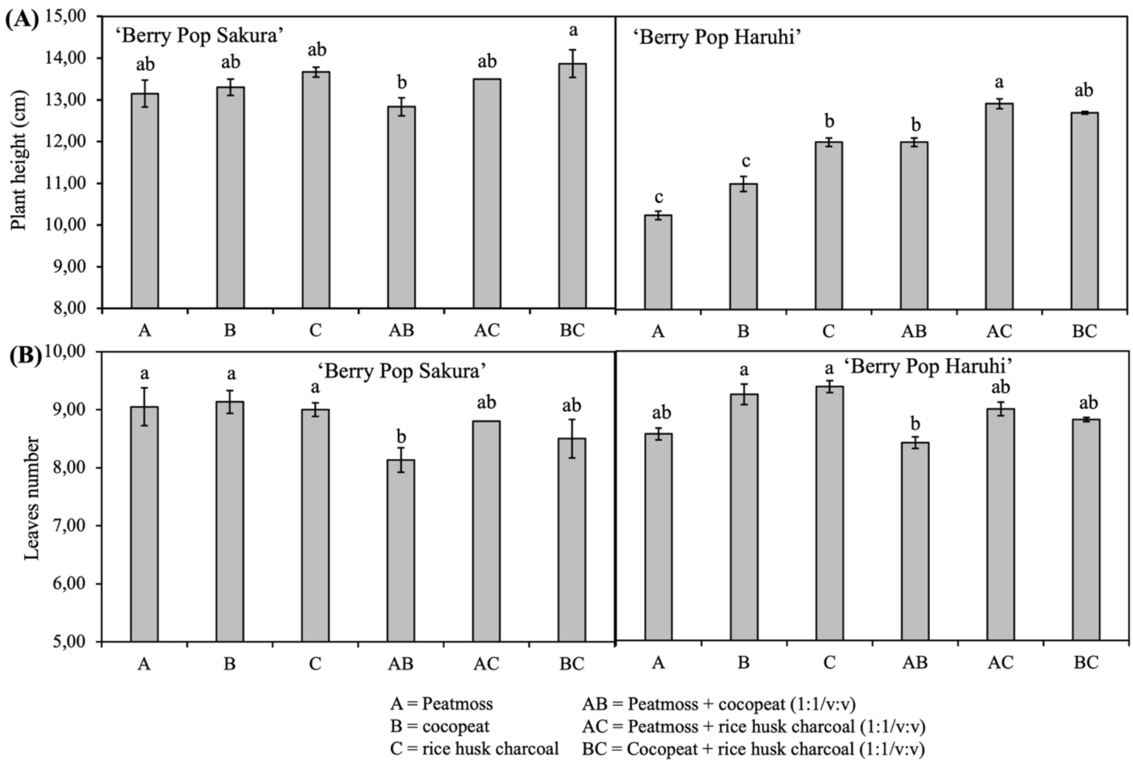


Fig. 1. Effect of different growing media on the plant height and leaf count of two strawberry cultivars. The mean value ± SE (n = 5) followed the same letter in each cultivar is not significantly different among the growing media, as determined by Tukey's tests at a significance level of $P < 0.05$.

Leaf count

In addition to plant height, the number of leaves is a parameter widely used as an indicator of vegetative growth in plants. Based on the statistical data analysis, the response of the number of leaves in both strawberry cultivars ('Berry Pop Sakura' and 'Berry Pop Haruhi') exhibited a similar tendency. Seedlings grown in peatmoss + cocopeat (AB) produced the lowest number of leaves in both cultivars compared to the other treatments. Meanwhile, the other growing media, both single and mixed, showed a comparable number of leaves among them (Fig. 1B).

Crown height

Based on the statistical data analysis, the use of single or mixed growing media did not affect changes in crown height in seedlings of either cultivar. However, it can be observed that the crown height of the two strawberry cultivars differs, with ‘Berry Pop Sakura’ exhibiting a higher crown height compared to ‘Berry Pop Haruhi’. At the same seedling age, the crown height of ‘Berry Pop Sakura’ ranges between 1.85 (AB) and 2.02 (AC), while for ‘Berry Pop Haruhi’, the crown height ranges from 1.47 (AB) to 1.75 (BC) (Fig. 2A).

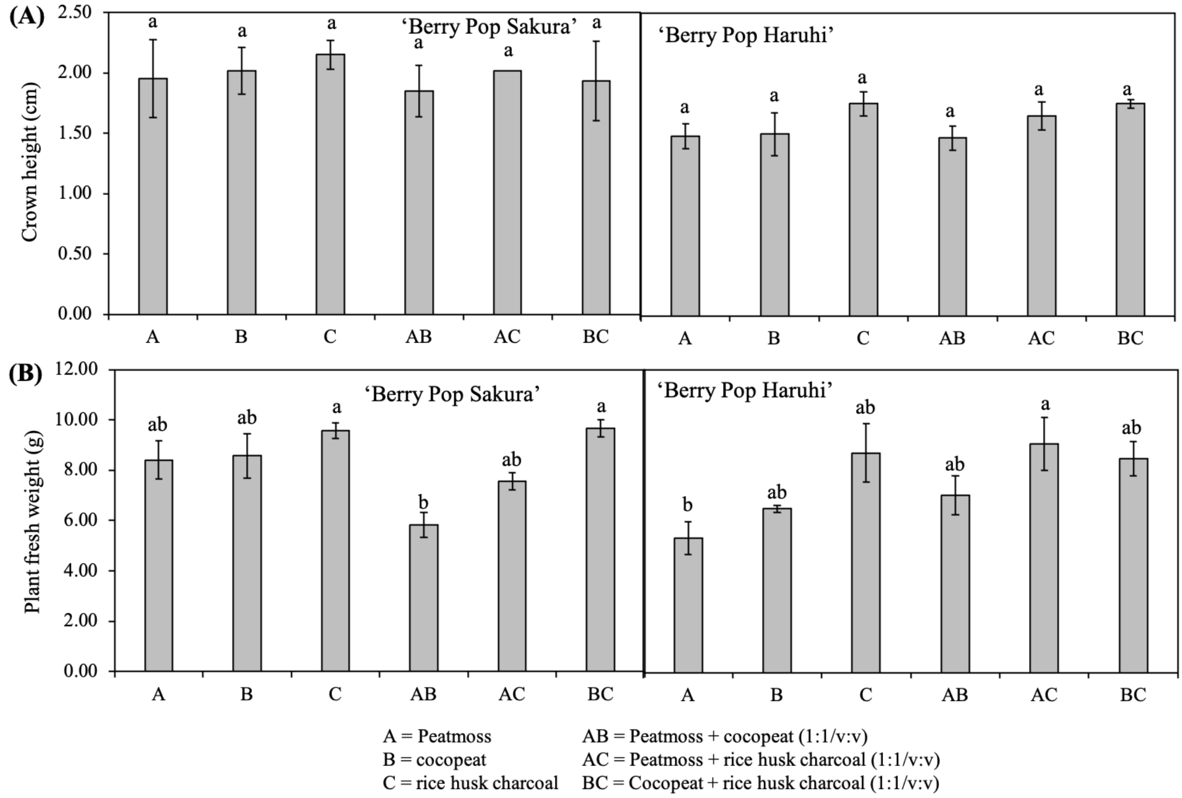


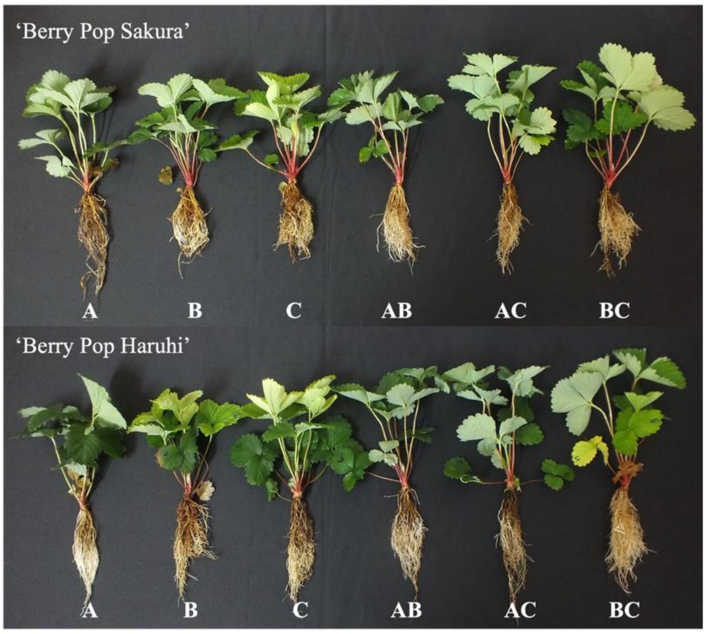
Fig. 2. Effect of different growing media on the crown height and plant fresh weight of two strawberry cultivars. Mean values ± SE (n =5) followed by the same letter in each cultivar are not significantly different among the growing media, as determined by Tukey’s tests (P<0.05).

Fresh weight

The two strawberry cultivars exhibited different tendencies in plant fresh weight in response to the use of various growing media. The use of peatmoss + cocopeat (AB) in ‘Berry Pop Sakura’ and peatmoss (A) in ‘Berry Pop Haruhi’ resulted in the lowest plant fresh weight compared to the other treatments. This indicates that the use of peatmoss as a growing medium—either alone or in combination—leads to slower plant growth, as reflected in the decreased plant fresh weight in both cultivars. The single growing medium of rice husk charcoal (C) or the mixture of cocopeat + rice husk charcoal (BC) enhanced plant fresh weight in ‘Berry Pop Sakura’, while for ‘Berry Pop Haruhi’, the highest fresh weight was obtained from peatmoss + rice husk charcoal (AC) (Fig. 2B).

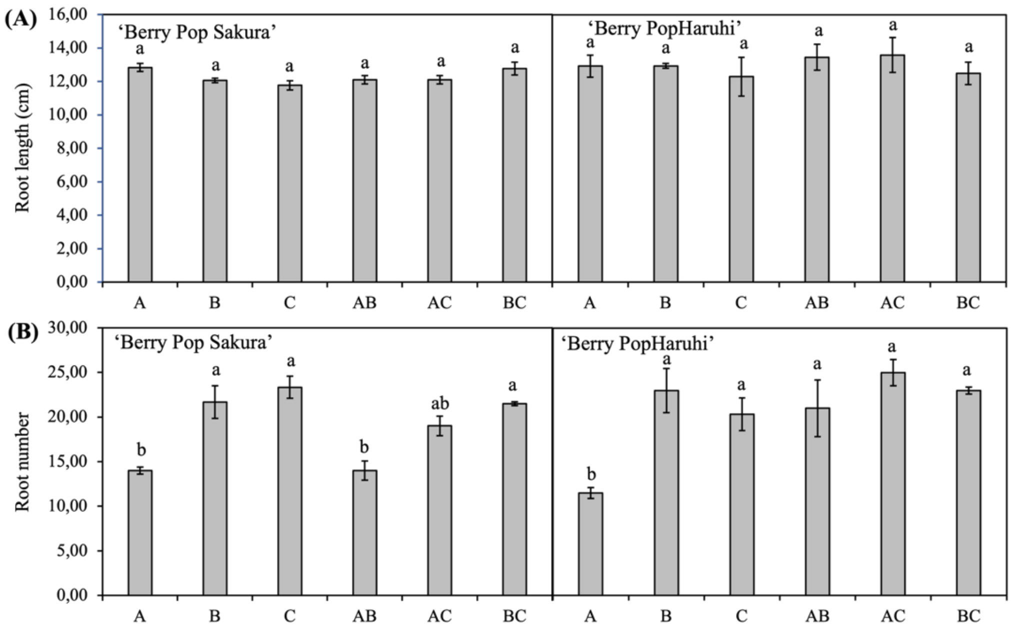
Root length

There were noticeable differences in seedling performance between the two strawberry cultivars (Fig. 3). Based on statistical data analysis, the two cultivars showed a similar tendency in root length in response to the different growing media. Statistically, the use of different growing media, whether single or mixed, did not significantly affect root length in either cultivar. However, in terms of absolute values, ‘Berry Pop Sakura’ produced shorter roots than ‘Berry Pop Haruhi’. The root length of ‘Berry Pop Sakura’ ranged from 11.77 cm (C) to 18.23 cm (A), whereas in ‘Berry Pop Haruhi’ it ranged from 12.30 cm (C) to 13.60 cm (AC) (Fig. 4A).



A = Peatmoss AB = Peatmoss + cocopeat (1:1/v:v)
B = cocopeat AC = Peatmoss + rice husk charcoal (1:1/v:v)
C = rice husk charcoal BC = Cocopeat + rice husk charcoal (1:1/v:v)

Fig. 3. Representative picture of strawberry seedlings 35 d after transplantation.



A = Peatmoss AB = Peatmoss + cocopeat (1:1/v:z)
B = cocopeat AC = Peatmoss + rice husk charcoal (1:1/v:v)
C = rice husk charcoal BC = Cocopeat + rice husk charcoal (1:1/v:v)

Fig. 4. Effect of different growing media on the root length and root count of two strawberry cultivars. Mean values ± SE (n = 5) followed by the same letter in each cultivar are not significantly different among the growing media, as determined by Tukey's test (P<0.05).

Root count

There were observable differences in seedling performance between the two strawberry cultivars (Fig. 3). Based on the statistical data analysis, the two cultivars exhibited a similar tendency in their root number in response to the different types of growing media. The use of different growing media, whether single or mixed, did not significantly affect the number of roots in either cultivar. However, in terms of the actual values, the number of roots in ‘Berry Pop Sakura’ was lower than that of ‘Berry Pop Haruhi’ (Fig. 4A).

Pearson’s correlation analysis

The present study employed Pearson’s correlation analysis to reveal the direction and strength of relationships among the observed variables. Pearson’s correlation analysis on morphological characteristics was performed for both ‘Berry Pop Haruhi’ and ‘Berry Pop Sakura’ cultivars (Fig. 5). In Figure 5, two significant positive correlations were identified: between plant fresh weight and crown height (P<0.05), and between plant fresh weight and plant height (P<0.01). Other variables in Figure 5A were not strongly correlated with one another (P<0.05). Plant height exhibited a very strong and significant positive correlation with root number (r = 0.93, P<0.01), indicating that vigorous shoot growth was supported by an extensive root system. Fresh weight also showed a strong positive association with leaf number (r = 0.84, ns), suggesting that leaf development contributes substantially to biomass accumulation. In contrast, root length was negatively correlated with both crown height (r = –0.58, ns) and leaf number (r = –0.42, ns), implying a possible trade-off between root elongation and shoot development (Fig. 5A).

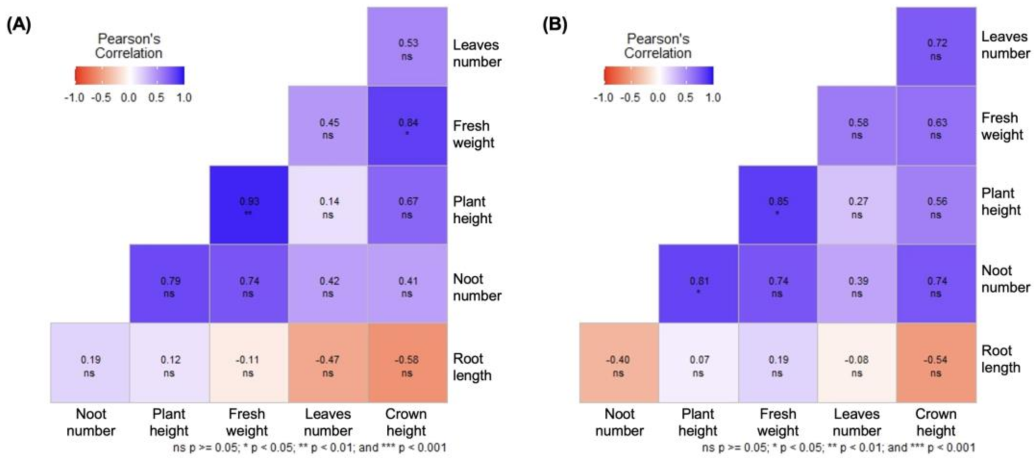


Fig. 5. Pearson’s correlation analysis on morphological characteristics of strawberry (**A**) ‘Berry Pop Haruhi’ and (**B**) ‘Berry Pop Sakura’.

In Figure 5B, there are also two significant positive correlations observed between the number of roots and plant height, and between plant height and plant fresh weight. Other variables in Figure 5B were not strongly correlated with one another (P<0.05). Similarly, significant correlations were recorded between plant height and root number (r = 0.81, P<0.05), as well as between plant height and fresh weight (r = 0.85, ns). Root number also showed a positive correlation with fresh weight (r = 0.74, ns), highlighting the importance of root system development in enhancing overall plant vigor. However, root length again displayed negative correlations with most shoot-related traits, including crown height (r = –0.54, ns) and root number (r = –0.40, ns) (Fig. 5B). These findings imply that plant height, plant fresh weight, crown size, and root number are important growth proxies for agronomical studies and research on strawberry.

Discussion

Growing media is one of the important factors that determines the successful growth of strawberry seedlings. A good planting medium is characterized by its ability to maintain moisture, provide good aeration and drainage, exhibit low salinity, and remain free from pests and diseases (Irawan and Kafiar, 2015). The cultivation of strawberries in soilless culture is highly beneficial, particularly for avoiding soil-borne diseases (Shahzad et al., 2018). Madhavi et al. (2021) reported that the growth and productivity of strawberry plants are closely correlated with the type of growing media used. The present study demonstrated that rice husk charcoal, when combined with peatmoss and cocopeat, significantly increased the seedling growth of the ‘Berry Pop Sakura’ and ‘Berry Pop Haruhi’ cultivars, although the magnitude and pattern of response varied between the two. Almorado (2019) and Costa et al. (2015) noted that each strawberry cultivar possesses different characteristics and adaptability to various planting media; therefore, selecting an appropriate growing medium is essential for achieving optimal plant growth and yield.

Rice husk is a by-product of the rice milling industry. Agustin et al. (2014) described rice husk charcoal as having high porosity, being lightweight, and enhancing aeration and drainage in the growing medium (Hidayat et al., 2020). Previous studies have reported that the use of rice husk charcoal as a growing medium can improve the growth of sweet corn and spinach (Managanta et al., 2023; Varela et al., 2013) by increasing soil porosity through decreased bulk density, which is associated with improved aeration and water-holding capacity to support plant growth (Sukaryorini and Arifin, 2007; Mishra et al., 2017). Despite these advantages, rice husk charcoal is relatively nutrient-poor and has low water-holding capacity, making it necessary to combine it with other growing media. The present study found that the seedling growth of 'Berry Pop Sakura' and 'Berry Pop Haruhi' grown in rice husk charcoal alone was slower than that observed in mixed media, especially mixtures involving rice husk charcoal with peatmoss or cocopeat. Both peatmoss and cocopeat have high water-holding capacity and cation exchange capacity (CEC), which help maintain the availability of water and nutrients around the plant roots (Susilawati, 2018).

Besides rice husk charcoal, strawberry seedlings cultivated in a single medium of cocopeat resulted in poor seedling growth. Cocopeat, with its high water-holding capacity, can create overly wet conditions in the growing medium, leading to root rot. Istomo and Valentino (2012) stated that cocopeat media contain micropores that can inhibit the movement of water, causing increased water retention and availability. The water-saturated condition frequently impedes gas exchange in the media. This occurs because the macropores that should be filled with air become filled with water, thereby impeding root respiration. Consequently, this condition inhibits the growth of plant roots, which eventually suppresses overall plant growth due to the increasingly acidic growing media. In addition, the high tannin content in cocopeat can slow plant growth performance.

The combination of rice husk charcoal and cocopeat or peat moss creates an ideal growing medium for strawberry seedlings. The porosity of the rice husk charcoal facilitates oxygen supply to the roots, while the high water-holding capacity of peat moss or cocopeat maintains water availability in the medium. The balance between aeration and moisture in the growing media is a crucial factor for strawberries, which have a relatively shallow, fibrous root system and are sensitive to overcrowding or waterlogging (Lieten, 2000). The lignocellulose and macro- and micronutrient content in cocopeat or peat moss supports the early growth of seedlings, and when combined with peat moss, the mixed media acquire mild acidic properties that can enhance the absorption of certain nutrients, especially micronutrients (Roidah, 2014). Thus, the combination of rice husk charcoal with peat moss or cocopeat not only improves the physical properties of the media but also supports nutrient availability and the activity of beneficial microbes within it.

Conclusion

The results of this study indicated that the type of growing media greatly affects the vegetative growth of strawberry seedlings. Rice husk charcoal or a mixture of cocopeat and rice husk charcoal as growing media effectively supports strawberry soilless culture under an ebb-and-flow system. This growing medium can increase the vegetative growth of two strawberry cultivars, 'Berry Pop Sakura' and 'Berry Pop Haruhi'. However, 'Berry Pop Haruhi' requires additional media such as peat moss to stabilize the pH of rice husk charcoal. In addition to providing agronomic benefits, the use of rice husk charcoal is also a good solution to address the problem of waste left over from the agricultural production of rice plants. Rice husk charcoal offers a sustainable and low-cost medium for hydroponic strawberry seedling production, with potential applications in commercial nurseries. Future studies may extend this approach to assess its impact on fruiting performance. These findings not only contribute to the improvement of seedling growth in hydroponic strawberry production but also highlight the importance of utilizing agricultural by-products for sustainable horticulture.

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Author Contributions

Conceptualization, SM, ES, RH; Data Curation, RB, ES, SYS, MN; Formal Analysis, SM, ES, RB; Funding Acquisition, SM, KE; Investigation, SM, ES, RH; Methodology, SM, ES; Resources, KE, YM; Supervision, SM, RB, RH; Validation, SM, RB; Visualization, SM, ES; Writing – Original Draft, SM, ES, SYS, RB, RH; Writing – Review and Editing, SM, RH, MN, KE, YM. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors indicate no conflict of interest in this work.

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