International Journal of Horticultural Science 2026, 32: 41-47.
https://doi.org/10.31421/ijhs/32/2026/15782

Effect of various growing media on growth and yield of lettuce in hydroponics system at Lalitpur, Nepal

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Summary: Hydroponic farming, particularly using the nutrient film technique, is gaining traction as a sustainable approach for cultivating leafy vegetables such as lettuce. However, the selection of appropriate growing media remains critical for optimizing plant growth and yield in a soilless system. A completely randomized design (CRD) was used in this study to assess the impact of six distinct growing media (sponge made up of cellulose, perlite, saw dust, sand, cocopeat, and rice husk) on the growth and yield of lettuce under NFT conditions at Mutha Agro Pvt. Ltd., Lalitpur, Nepal. Analysis of variance (ANOVA) in RStudio (v4.4.1) was used to examine the data, and Tukey HSD test was used to differentiate treatment means at a 5% significance level. Lettuce grown in sponge media exhibited the highest performance in terms of number of leaves (11), longest leaf length (17.55 cm), greatest leaf width (9.43cm), plant height (35.81 cm), root length (12.51 cm), canopy diameter (36.07 cm), and stem diameter (0.62 cm). The highest fresh root weight (24.67 g) and moisture loss (98.7%) were obtained by perlite. The highest yield was recorded in sponge (146.45 g), followed by perlite (139.65 g), while the lowest was observed in rice husk (117.83 g). Overall, sponge made up of cellulose proved to be the most effective growing medium for hydroponic lettuce cultivation using NFT, followed by perlite. These findings can help guide growers in selecting suitable substrates to improve yield and quality in hydroponic production systems.

Ghimire, S., Giri, H. N., Pandey, U., Kafle, K., Budha, S. (2026): Effect of various growing media on growth and yield of lettuce in hydroponics system at Lalitpur, Nepal. International Journal of Horticultural Science 32: 41-47. https://doi.org/10.31421/ijhs/32/2026/15782

Key words: CRD, growth media, hydroponics, lettuce, nutrient film technique, yield

Introduction

Hydroponics is a plant cultivation technique that replaces soil with a water-based medium that has an optimal combination of minerals that are essential for plant growth. (Maharana & Koul, 2011). In hydroponics system, various substrates such as cocopeat, perlite, coir, vermiculite, and other inert media are used to support plant growth (Brock, 2019). The main goal is to give the right nutrients to the plants at the right time (Roosta & Afsharipoor, 2012). This system is widely used by commercial growers, hobbyists, and small-scale farmers to grow vegetables like tomatoes, lettuce, cucumbers, peppers, and ornamental plants such as herbs and roses (Shrestha & Dunn, 2017). Part of the Asteraceae family, lettuce (Lactuca sativa L., 2n=2x=18) is one of the leafy vegetables that is most frequently cultivated in hydroponic systems as because of its considerable nutritional content, which includes iron, folate, vitamins A, C, and K, and fiber (Khodijah et al., 2021; Ahmed et al., 2021). Lettuce has been utilized as a therapeutic herb in the past because of its secondary metabolites. In several eastern nations, such Egypt and China, people eat lettuce stems in different ways (Sapkota, 2019; Ryder, 1986). The Nutrient Film Technique (NFT) involves placing plant roots in shallow, sloping channels so a thin stream of nutrient solution flows past them. This keeps roots moist and aerated while avoiding waterlogging (Mohammed, 2016; Tawaha, 2018). Crops like lettuce, leafy vegetables and herbs can be grown in Nutrient film technique (Sookoo, 2016). A suitable growing medium is essential in hydroponics for water and nutrient access and root support, with options such as sand, perlite, gravel, and cocopeat acting as mechanical substitutes for soil (Jacobs & Luna, 1990; Gaikwad & Maitra, 2020). The performance of hydroponically grown lettuce is significantly influenced by the choice of growing media, affecting root development, aeration, water retention, and nutrient uptake (Dholwani & Marwadi, 2018). However, hydroponics requires high technical knowledge, experience, and financial investment compared to traditional systems (Janker, 2018; Khan, 2020). Challenges include setup costs, dependency on electricity, water quality issues, disease risks, and the need for constant system monitoring (Sardare, 2013; Yadav, 2020; Mccray, 2023). While hydroponics reduces water usage − up to 90% less than conventional farming − and eliminates soil-borne pests and diseases, selecting the appropriate growing medium remains a key factor in maximizing yield and quality (Waiba & Sharma, 2020; Nejim, 2019; Saldinger & Rodov, 2023). This study, therefore, aims to evaluate the effectiveness of different growing media on lettuce performance, thereby supporting hydroponic growers in enhancing system sustainability productivity, and economic viability.

Materials and methods

Experimental site

The research was conducted out at Mutha Agro Pvt. Ltd. in Thecho, Lalitpur (1350 masl). In Bagmati province, Lalitpur

District is situated at 27.541967 latitude and 85.334297 longitude, with a height of 1350 meters above sea level and a total size of 50.67 square kilometers. During the experiment a maximum of 32 ºC and a minimum of 12 ºC were recorded.

Experimental design

The effects of six treatments on CRD was studied in three replications in this experiment. The experiment's hydroponics system, which used the nutrient film technique, featured 120 holes for 120 plants. It had six layers, each of which held six interconnected PVC pipes, and measured 19x3x3 cm. There were 30 holes in each PVC pipe, with 180 holes in each tier and 1080 holes overall. The diameter of each hole was 6 cm, and they were spaced 8 cm apart. Lettuce, the most widely used salad produce in Nepali families, was the crop chosen. Growing media, which included sponge created from cellulose, cocopeat, perlite, sand, rice straw, and saw dust, was the other component of the experiment. The TDS meter and pH were the instruments utilized in this study.

R1	T1	T2	T3	T4	T5	T6
R2	T2	T3	T4	T5	T6	T1
R3	T6	T5	T3	T4	T1	T2

Figure 1: Layout of experiment

Cultivation practices and data collection

Seedlings were raised in 50-hole trays (2 cm depth) using a 1:1 mix of sun-dried cocopeat and organic fertilizer. Two seeds were sown per hole at ¼ inch depth in early April. Trays were placed in water trays (40 × 28.5 cm) for moisture and irrigated daily in the evening. After germination, trays were moved to sunlight, and seedlings were thinned to one per hole at the 3–4 leaf stage. Transplanting was done at the 4–5 leaf stage into an NFT hydroponic system using six growing media: sponge, cocopeat, perlite, sand, rice husk, and saw dust (***Table 1***). The growing media were placed in perforated plastic cups for flow of water and root growth. The system used 250 L of water, running 16 hours/day with a motor for circulation. Nutrients A and B were added at 0.5 L each per 1 L of water, totaling 50 L each. EC, pH, and TDS were regularly monitored. Nutrients and water were refilled by 25% every 7 days. To control aphids, 3 ml/L of Nimbicide was sprayed twice at weekly intervals starting from week two. The first harvest was done at 30 DAT, second at 40 DAT followed by final harvesting at 50 DAT by uprooting the plant, separating leaves and roots from the plastic cup.

Table 1. Treatment details of the experiment at Thecho, Lalitpur, 2024.

Treatments	**Growth media**
T_1	Cocopeat
T_2	Perlite
T_3	Rice husk
T_4	Sand
T_5	Saw dust
T_6	Sponge

The total number of leaves, length of root, leaf length, height of plant, canopy diameter, leaf width, and diameter of the stem were all recorded five times after ten days of transplantation. After 50 DAT, the fresh and dry weight of root were measured during the final harvest. Out of 120 plants 90 plants and five plants per replication were used to record the data. The parameters recorded were leaves number, length of root (cm), length of longest leaf (cm), plant height (cm), the canopy area (cm), leaf width (cm), diameter of stem (cm), fresh and dry mass of root (g) and plant yield (mt/ha).

Statistical analysis

Data were organized in Microsoft Excel and analyzed in R (version 4.4.1). A one-way ANOVA (CRD) tested treatment effects. When significant at $\alpha = 0.05$, means were compared using Tukey's HSD (***Table 2***).

Table 2. Table of variance analysis for the CRD experiment.

Source of variation	**Degree of freedom**	**SS**	**MSS**	**Computed 'F**
Treatment	t-1 (6-1) =5	TrSS	TrSS/t-1	TrMSS/EMSS
Error	t(r-1) 6(3-1) =1	ESS	ESS/n-t	
Total	tr-1 (6*3-1) =1	TSS		

Results

Number of leaves

The study showed that the number of plant leaves at each observation was significantly affected by the growing media used in hydroponics. The average number of leaves at 10 DAT (days after transplanting) was 4.91, compared to 9.29 in the previous harvest. At the first harvest (30 DAT) and second harvest (40 DAT), the growing media sponge had the most leaves (13) as in ***Table 3***. When lettuce and sponge were used as growing material, the plant initially produced the most leaves, an observation that maintained until harvest, with the exception of 20 DAT. The interaction between rice husk and lettuce with cocopeat resulted in the plants with the fewest leaves across all observation dates till harvest.

Leaf length

The study discovered that whereas growing media at 20 DAT and 50 DAT had little effect on leaf length, growing media in hydroponics had significant effects at 10 DAT, 30 DAT, and 40 DAT. At 10 DAT, the average leaf length was 7.82 cm; at the final harvest, it was 16.11 cm. Using sponge as growing media, the leaf length was statistically longest at 30 and 40 days as presented in ***Table 4***. The interaction of lettuce with rice husk and cocopeat at the second harvest had the shortest leaf length statistically, measuring 12.89 cm in both treatments. This is because sponges allows the roots to get moisture while still keeping enough oxygen, which is needed for root breathing and building dry matter.

Leaf width

At each observation date, the study discovered that the hydroponic growing media significantly affected the hydroponic

Table 3. Effect of different growing media on leaves number of lettuce under hydroponics system at Thecho, Lalitpur, 2024.

	Number of leaves				
Treatments	10 DAT	20 DAT	30 DAT	40 DAT	Final harvest
Cocopeat	4^{c}	7^{b}	7^{c}	9^{c}	7^{b}
Perlite	5^{ab}	7^{b}	10^{b}	11^{b}	10^{a}
Rice husk	4^{c}	7^{b}	8^{c}	8^{c}	8^{ab}
Sand	5^{ab}	9^{a}	10^{b}	12^{ab}	10^{a}
Saw dust	5^{bc}	8^{a}	11^{b}	11^{b}	9^{ab}
Sponge	6^{a}	7^{b}	13^{a}	13^{a}	11^{a}
SEm (±)	0.18	0.18	0.39	0.41	0.62
$HSD_{0.05}$	0.85	0.86	1.89	1.98	2.96
F-test	***	***	***	***	**
CV, (%)	6.36	4.19	6.98	6.74	11.62
Grand mean	4.91	7.53	9.87	10.75	9.29

Note: Coefficient of Variation (CV), Standard Error of Mean (SEM), and Tukey's HSD0.05(Least Significant Difference)) at the 5% level of significance. The means in the column that have the same letter (s) in superscript show that, at the 0.05 level of significance, there is no significant difference between treatments; "***." Significant at a significance level of 0.001

Table 4. Effect of different growing media on leaf length of lettuce under hydroponics system at Thecho, Lalitpur, 2024.

	Leaf length (cm)				
Treatments	10 DAT	20 DAT	30 DAT	40 DAT	Final harvest
Cocopeat	5.77^{c}	8.79	10.91^{ab}	12.89^{b}	15.65
Perlite	8.00^{abc}	11.83	12.64^{ab}	14.97^{ab}	15.61
Rice husk	6.17^{bc}	8.69	10.11^{b}	12.89^{b}	16.76
Sand	10.40^{a}	13.53	14.76^{a}	16.23^{ab}	16.68
Saw dust	7.64^{abc}	13.96	11.15^{ab}	14.07^{ab}	14.48
Sponge	8.97^{ab}	14.71	14.53^{a}	17.55^{a}	17.53
SEm (±)	0.62	1.59	0.81	0.75	0.74
$HSD_{0.05}$	2.98	-	3.88	3.59	-
F-test	**	ns	**	**	ns
CV, (%)	13.89	23.12	11.46	8.88	7.97
Grand mean	7.82	11.91	12.34	14.76	16.11

Note: Coefficient of Variation (CV), Standard Error of Mean (SEM), and Tukey's HSD0.05(Least Significant Difference)) at the 5% level of significance. The means in the column that have the same letter (s) in superscript show that, at the 0.05 level of significance, there is no significant difference between treatments; "***." Significant at a significance level of 0.001

Table 5. Effect of different growing media on leaf width of lettuce under hydroponics system at Thecho, Lalitpur, 2024.

	Leaf width (cm)		
Treatments	30 DAT	40 DAT	Final harvest
Cocopeat	5.61^{b}	6.95^{bc}	5.90^{d}
Perlite	7.91^{ab}	9.91^{ab}	7.81^{b}
Rice husk	6.08^{ab}	6.37^{c}	6.13^{cd}
Sand	9.55^{a}	9.53^{ab}	8.67^{ab}
Saw dust	7.94^{abc}	8.94^{abc}	7.62^{bc}
Sponge	8.24^{ab}	10.53^{a}	9.43^{a}
SEm (±)	0.77	0.62	0.33
$HSD_{0.05}$	3.66	2.97	1.57
F-test	*	**	***
CV, (%)	17.68	12.44	7.53
Grand mean	7.55	8.70	7.59

Note: Coefficient of Variation (CV), Standard Error of Mean (SEM), and Tukey's HSD0.05(Least Significant Difference)) at the 5% level of significance. The means in the column that have the same letter (s) in superscript show that, at the 0.05 level of significance, there is no significant difference between treatments; "***." Significant at a significance level of 0.001

Table 6. Effect of different growing media on plant height of lettuce under hydroponics system at Thecho, Lalitpur, 2024.

	Plant height (cm)				
Treatments	10 DAT	20 DAT	30 DAT	40 DAT	Final harvest
Cocopeat	11.63[b]	18.33[c]	21.43[b]	23.08[c]	27.03
Perlite	15.00[ab]	22.86[b]	24.03[ab]	27.52[bc]	27.56
Rice husk	12.77[b]	18.75[c]	22.67[ab]	24.89[c]	25.53
Sand	19.63[a]	27.38[a]	29.58[a]	39.49[ab]	28.01
Saw dust	15.57[ab]	26.61[a]	23.31[ab]	31.75[ab]	24.20
Sponge	19.60[a]	25.91[ab]	29.22[a]	35.81[a]	29.07
SEm (±)	1.04	0.73	1.51	1.26	1.08
$HSD_{0.05}$	4.96	3.47	7.21	6.01	-
F-test	***	***	**	***	ns
CV, (%)	11.51	5.42	10.50	7.45	6.97
Grand mean	15.7	23.30	25.03	29.42	26.9

Note: Coefficient of Variation (CV), Standard Error of Mean (SEM), and Tukey's HSD0.05(Least Significant Difference)) at the 5% level of significance. The means in the column that have the same letter (s) in superscript show that, at the 0.05 level of significance, there is no significant difference between treatments; "***." Significant at a significance level of 0.001

Table 7. Effect of different growing media on canopy diameter of lettuce under hydroponics system at Thecho, Lalitpur, 2024.

	Canopy diameter (cm)				
Treatments	10 DAT	20 DAT	30 DAT	40 DAT	Final harvest
Cocopeat	5.46[c]	10.77[c]	12.89[c]	29.01[bc]	23.57
Perlite	9.61[b]	19.83[a]	22.20[abc]	34.03[ab]	25.43
Rice husk	7.06[bc]	11.39[bc]	13.61[bc]	27.59[c]	21.89
Sand	13.10[a]	22.39[a]	24.45[ab]	35.35[a]	26.01
Saw dust	9.44[b]	18.53[ab]	18.42[ab]	33.20[ab]	23.20
Sponge	12.87[a]	21.67[a]	25.64[a]	36.07[a]	27.45
SEm (±)	0.54	1.53	2.34	1.10	1.44
$HSD_{0.05}$	2.59	7.29	11.16	5.24	-
F-test	***	***	**	***	ns
CV, (%)	9.88	15.25	20.83	5.87	10.18
Grand mean	9.58	17.43	19.53	32.54	24.59

Note: Coefficient of Variation (CV), Standard Error of Mean (SEM), and Tukey's HSD0.05(Least Significant Difference)) at the 5% level of significance. The means in the column that have the same letter (s) in superscript show that, at the 0.05 level of significance, there is no significant difference between treatments; "***." Significant at a significance level of 0.001

Table 8. Effect of different growing media on root length of lettuce under hydroponics system at Thecho, Lalitpur, 2024.

	Root length (cm)				
Treatments	10 DAT	20 DAT	30 DAT	40 DAT	Final harvest
Cocopeat	2.46[c]	5.33[d]	6.13	5.54[b]	7.52[b]
Perlite	3.69b[c]	5.23[d]	5.14	7.39[ab]	9.77[ab]
Rice husk	4.82[ab]	6.93[bc]	7.63	6.23[b]	6.67[b]
Sand	6.24[a]	8.74[a]	7.41	8.10[ab]	8.85[ab]
Saw dust	3.93[bc]	8.32[ab]	7.77	7.11[ab]	7.98[b]
Sponge	4.21[abc]	5.97[cd]	8.14	9.93[a]	12.51[a]
SEm (±)	0.43	0.33	0.69	0.62	0.79
$HSD_{0.05}$	2.06	1.57	-	2.96	3.75
F-test	**	***	ns	**	**
CV, (%)	17.78	8.52	17.06	14.65	15.41
Grand mean	4.22	6.75	7.03	7.38	8.88

Note: Coefficient of Variation (CV), Standard Error of Mean (SEM), and Tukey's HSD0.05(Least Significant Difference)) at the 5% level of significance. The means in the column that have the same letter (s) in superscript show that, at the 0.05 level of significance, there is no significant difference between treatments; "***." Significant at a significance level of 0.001

leaf width. Between the first and last harvests, the plant's average leaf width ranged from 7.55 cm to 7.59 cm. When lettuce was grown with sand and sponge as a growing medium, the leaf breadth was statistically the longest. At the final harvest, the interaction of lettuce with cocopeat had the shortest leaf width statistically, measuring 5.90 cm, respectively as indicated in ***Table 5***. The widest leaves were found in lettuce cultivated in sand, sponge.

Plant height

The study showed that, with an exception of 50 DAT, growing media in hydroponics significantly affected plant height. From 15.7 cm at 10 DAT to 26.9 cm at final harvest (***Table 6***), the average plant height varied. The first harvest (30 DAT) using sand and sponge had the statistically greatest plant height, whereas the second harvest (40 DAT) using sponge as growing media had the longest plant height. From the data, the interaction of lettuce with rice husk and cocopeat at the second harvest produced the least plant height, measuring 24.89 and 23.08 cm, respectively. The tallest plants were lettuce cultivated in sponge and sand.

Canopy diameter

The study found out that growing media in hydroponics had significant impact on canopy diameter at all date of observation except 50 DAT. The average canopy diameter varied from 9.58 cm at 10 DAT to 24.59 cm at final harvest. The canopy diameter was statistically longest in both the harvest with lettuce using sponge as a growing media. The interaction of lettuce with rice husk and cocopeat at the first and second harvests had the shortest canopy diameter (***Table 7***).

Root length

The study found out that growing media in hydroponics had significant impact on root length at all date of observation from 10 DAT to 50 DAT except 30 DAT. The average plant root length varied from 4.22 cm at 10 DAT to 8.88 cm at final harvest. The plant root length was statistically longest with growing media sponge at both the harvest as reflected in ***Table 8***. Similarly, lettuce grown on cocopeat and rice husk as a growing medium had the shortest root length.

Stem diameter

The study found out that growing media in hydroponics had significant impact on stem diameter in hydroponics at the date of observation. The average stem diameter of plant was 0.49 cm at the harvest. The stem diameter was statistically highest with lettuce using perlite (0.69 cm), sand (0.61 cm) and sponge (0.62 cm) as a media. The interaction of lettuce with rice husk (0.32 cm), cocopeat (0.29 cm), and saw dust (0.42 cm) produced the smallest stem diameter significantly as in ***Table 9***.

Fresh and dry weight of root

The study found that growing media in hydroponics had a significant impact on weight, both fresh and dried at the observation. At 50 DAT, the fresh weight of root was highest with the growing media perlite which is 24.67 g, followed by all other growing media used during the observation as in ***Figure 2a.*** Similarly, the moisture loss % was highest with the growing media perlite, followed by all other growing media used during the observation as shown in ***Figure 2b***.

Table 9. Effect of different growing media on stem diameter of lettuce under hydroponics system at Thecho, Lalitpur, 2024.

Stem diameter (cm)	
Treatments	**Final harvest**
Cocopeat	0.29^{b}
Perlite	0.69^{a}
Rice husk	0.32^{b}
Sand	0.61^{a}
Saw dust	0.42^{ab}
Sponge	0.62^{a}
SEm (±)	0.05
$HSD_{0.05}$	0.27
F-test	**
CV, (%)	20.69
Grand mean	0.49

Note: Coefficient of Variation (CV), Standard Error of Mean (SEM), and Tukey's HSD0.05(Least Significant Difference)) at the 5% level of significance. The means in the column that have the same letter (s) in superscript show that, at the 0.05 level of significance, there is no significant difference between treatments; "***." Significant at a significance level of 0.001

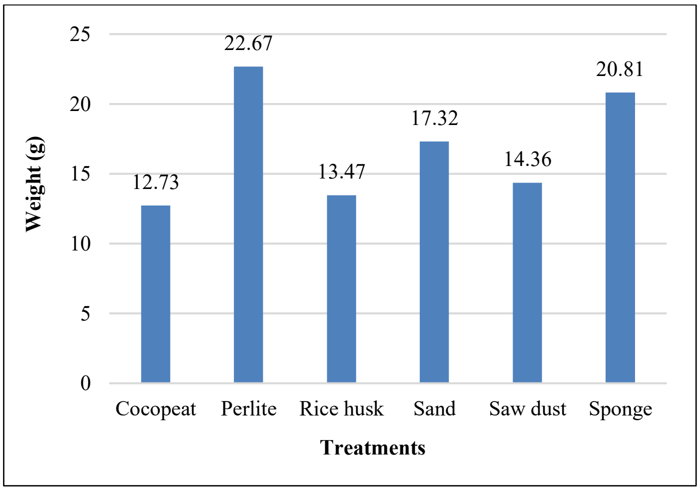

Figure 2a. Effect of different growing media on fresh root weight of lettuce under hydroponics system at Thecho, Lalitpur, 2024.

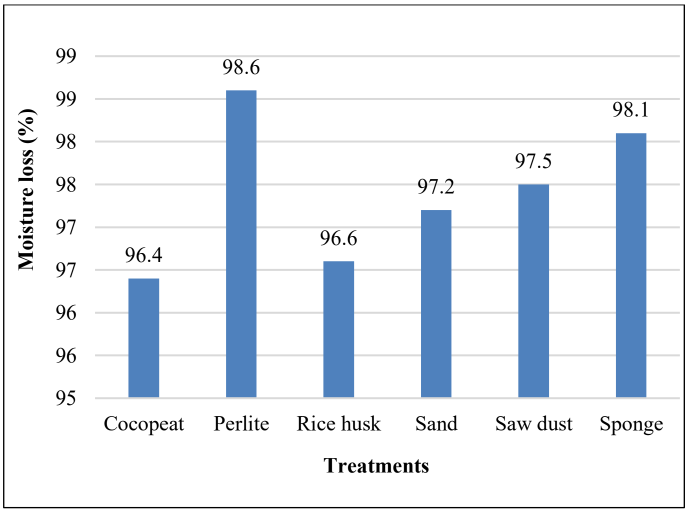

Figure 2b. Effect of different growing media on dry root weight of lettuce under hydroponics system at Thecho, Lalitpur, 2024.

Table 10. Effect of different growing media on average yield of lettuce under hydroponics system at Thecho, Lalitpur, 2024.

Treatments	Yield of plant (g/plant)	Yield of plant (mt/ha)
Cocopeat	127.29[c]	21.21[b]
Perlite	139.65[b]	23.27[a]
Rice husk	117.83[e]	19.63[b]
Sand	127.85[c]	21.36[b]
Saw dust	121.96[d]	20.32[b]
Sponge	146.45[a]	24.4[a]
SEm (±)	0.57	0.54
$HSD_{0.05}$	2.74	1.74
F-test	***	***
CV, (%)	0.76	4.61
Grand mean	352.75	21.68

Note: Coefficient of Variation (CV), Standard Error of Mean (SEM), and Tukey's HSD0.05(Least Significant Difference)) at the 5% level of significance. The means in the column that have the same letter (s) in superscript show that, at the 0.05 level of significance, there is no significant difference between treatments; "***." Significant at a significance level of 0.001

Plant yield

The study found that growing media in hydroponics had a significant impact on plant yield at the observation. At final harvest, the plant yield was highest with the growing media sponge which is 146.45 g, followed by perlite (139.65 g). Statistically, the lowest plant yield was noted during the lettuce interaction with rice husk (117.83 g) as indicated in ***Table 10***.

Discussion

Among the different growing media tested, sponge made from cellulose consistently performed better than others in helping lettuce grow and produce more. It supported the most leaf growth compared to all other substrates. This is because the sponge holds a lot of water but allows air to reach the roots. This balance helps the plant take in nutrients more efficiently and grow strong shoots. These qualities help the plant get enough water and nutrients while keeping the roots well-aerated, which is important for healthy plant growth (Pinkerton, 2022). The result are similar to the findings of Awang et al. (2009), who found that sponge media helps plants grow strong roots and increase root mass in hydroponic crops because it maintains a good balance of air and moisture.

Sponge also performed notably well, particularly in promoting leaf expansion and height of the plant. Chhetri et al. (2022) similarly observed enhanced leaf area development in leafy vegetables grown in sponge and cocopeat due to their consistent nutrient availability and moisture retention.

On the other hand, rice husk, though organic and cost-effective, demonstrated lower water retention capacity compared to cocopeat, which might have led to suboptimal moisture conditions, negatively affecting leaf growth. These results match with the research conducted by Gaikwad (2020), who suggested that while organic media like saw dust and rice husk are eco-friendly, their physical properties may limit their effectiveness compared to more inert substrates like sponge.

Sponge also resulted in the longest root length, which is likely due to its superior ability to maintain moisture and provide stable mechanical support. Furthermore, it proved advantageous during transplanting, as it minimizes root damage and is lightweight and easy to handle (Chettri, 2022).

Ultimately, the highest yield was obtained from plants grown in sponge media. These results are consistent with earlier research by Chhetri (2021) and Pinkerton (2022), who reported that sponge and cocopeat are among the most effective media for maximizing lettuce yield in hydroponic systems due to their excellent moisture and aeration balance, mechanical support, and compatibility with nutrient delivery.

Conclusions

The highest leaves number, length of root, length of leaf, leaf width, plant height, canopy area, root length, thickest stem diameter and yield were found to be significantly higher with the growth media sponge for hydroponic lettuce cultivation in nutrient film technique. However, the and highest fresh and dry weight of root was observed in perlite as growing media**.** The most effective growing media was sponge as the sponge used in this study was cellulose-based, it is biodegradable and can be composted or safely disposed of, which adds a sustainability advantage compared with synthetic sponges, which provided a high yield and favorable leaf characteristics whereas, rice husk was the least effective among all other growing media.

Acknowledgements

The authors are grateful and want to emanate immense thanks and acknowledge to Agriculture and Forestry University, Valley Krishi Campus and Mutha Agro Pvt. Ltd., for their invaluable guidance and support throughout this research.

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