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Growth and Yield of Hydroponic Lettuce as Influenced by Different Growing Substrates

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ABSTRACT

The experiment was conducted in the greenhouse at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh during September 2015 to February 2016. Four different types of growing substrates, such as, M_1 = 60% rice husk + 30% coconut coir + 10% vermicompost, M_2 = 60% coconut coir + 30% brocken brick + 10% vermicompost, M_3 = 60% sawdust + 30% brocken brick + 10% vermicompost, and M_4 = 60% ash + 30% brocken brick + 10% vermicompost were used in this experiment. Growth and physiological parameters of lettuce were measured in this experiment. The maximum number of leaves per plant (21.44) and the highest fresh weight (92.49 g plant^{-1}) were recorded from M_1 while the lowest in M_3. Therefore, the study revealed that the rice husked based growing substrates can be used for growing lettuce cv. 'Legacy' in aggregate soilless system in the tropics like Bangladesh.

INTRODUCTION

Hydroponic crop production become popular throughout the world in current years. Hydroponic is a modern and developed crop production technique where crops are grown in restrained environment in solid or liquid media without any soil by providing fundamental and essential nutrients. It is highly productive, conservative of water and land, and protective of the environment. Hydroponics has proved to be an excellent alternative crop production system and it is highly exacting and demanding systems that ensure better production of crops (Savvas 2003; Rahman et al. 2018). In this method there is no need of arable land where production is possible through the year round. In this way crop production is possible round the year without applying any pesticide. A hydroponic system enables a considerable reduction of fertilizer application and a drastic restriction or even a complete elimination of nutrient leaching from greenhouses to the environment (Avidan 2000; Rahman et al. 2017). Hydroponics offers a means of control over soil-borne diseases and pests, which is especially desirable in the tropics, where infestations are major concern.

The material that plants grow is called the "growing medium". Different ingredients are used in varying combinations to create homemade or commercial growing media. By understanding the functions of growing media, one can appreciate the qualities of individual types and select which one might work best for container vegetable garden. The choice is very important because plants are dependent on a comparatively small volume of growing medium. In Bangladesh, soilless culture of vegetable is very important, as there is shortage of land for crop cultivation, and agricultural lands are used for accommodation of over population. On the other hand, vegetable production and consumption in Bangladesh is very low. As a result, people of Bangladesh are suffering from many serious health diseases (FAO 2018). Soilless culture allows for uninterrupted year-round vegetable production and can increase the yield. After developing a hydroponic protocol people of Bangladesh can easily produce their daily requirements of vegetables by creating kitchen hydroponics garden that will increase the socio-economic condition of Bangladesh.

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Lettuce (*Lactuca sativa* L.) is most popular amongst the salad vegetable crops and in demand or need by the local markets throughout the year. Raw leaf lettuce has concentrations of vitamins, viz, vitamins C and A. It has also contained calcium, potassium, iron, protein and fiber. It is good source of vitamins and a popular food for weight conscious consumers because of its low kilo joule content (Niederwieser 2001; Maboko 2007). Leaf lettuce is cultivated mainly in our country in open fields as well as under greenhouse conditions. It has been found that simple hydroponics techniques such as the floating culture were successful in growing leafy vegetables. This is assured by adequate fertilizing, steady supply of water and cool temperature (Fallovo 2009). By considering the above literatures, the present study was aimed to find out effect of different growing substrates on growth and yield of hydroponic lettuce.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted in the in greenhouse at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh during September 2015 to February 2016. The site is situated between $23^{0}41^{'}$ N latitude and $90^{o}22^{'}$E longitude.

Plant materials and other materials

Seeds of lettuce seeds cv. "Legacy" were used in the experiment. The seeds which were collected from Siddik Bazar, Dhaka were kept in a sealed packet. The plastic boxes were collected from Farmgate, Dhaka. Experimental chemicals were bought from Tikatolli, Dhaka. The growing media were collected from Gazipur, Bogura and Narayanganj. Some white color polythene papers were collected from Boubazar, SAU. Different types of daily instruments also used for many purposes to complete the experiment.

Experimental design and treatment

The experiment was conducted in a completely randomized design (CRD) with four replications. The four different types of growing substrate mixtures were M_1 = 60% rice husk + 30% coconut coir + 10% vermicompost, M_2= 60% coconut coir+ 30% brocken brick + 10% vermicompost, M_3 = 60% sawdust + 30% brocken brick + 10% vermicompost, and M_4 = 60% ash + 30% brocken brick + 10% vermicompost.

Growing Environment

Sixteen different plastic boxes were used for culturing the plants. Boxes were filled with different substrates mixture according to the treatments. Lettuce seedlings were transplanted and nutrient solution was applied in different boxes. In every box, there were six plants used as experimental unit. The room was kept clean and tidy during the time of the experiment. Daily supervision was done to maintain the plants. Rahman and Inden (2012) solution was applied in different boxes.

Harvesting

The crop was harvested after 42 days of sowing. Harvesting of the crop was done box wise. It was done by uprooting the plants by hand slowly and carefully. The growing media and fibrous roots adhering to the roots were removed and cleaned

Data collection

Data were collected from each plant for plant height, leaves breadth, leaves length, number of leaves plant^{-1}, fresh weight plant^{-1}, percent dry matter plant^{-1}.

The percentage of dry matter of plant was calculated by the following formula.

$$\%\ \text{Dry matter of plant} = \frac{\text{Constant dry weight of plant}}{\text{Fresh weight of plant}} \times 100$$

Statistical analysis

Data analysis was done using the IBM SPSS software (version 20.0) and mean separation was done by Tukey's test at 5% level of significance.

RESULTS AND DISCUSSION

Plant height

Plant height of lettuce was not significant at 7 days after transplanting (DAT), but it was significantly differed at 14, 21, 28, 35 and 42 DAT due to different types of growing substrates (Table 1). The plant heights increased in increasing days until maturity. At 7 DAT, the tallest plant (6.39 cm) was found in M_3 and the shortest (5.89 cm) was found in M_1. Similar trends of plant heights were found at 14, 21, 28, 35 and 42 DAT. The results revealed that the maximum plant heights at all dates were found in plants grown in media mixture of 60% rice husk + 30% coconut coir + 10% vermicompost (M_1) which was statistically similar to that of media mixture of 60% coconut coir+ 30% brocken brick + 10% vermicompost (M_2). This might be due to proper aeration, water-holding capacity, lower bulk density, and biostability of M_2 treatment as compared with other treatments (Rahman et al. 2018).

Meanwhile the shortest plants height at all dates were observed in the plants grown in the media mixture of 60% sawdust + 30% brocken brick + 10% vermicompost (M_3). These might be due to improve physical and chemical properties of M_1 and M_2 that were discussed earlier. Lemaire

Table 1. Effects of growing substrates on plant height of lettuce at different days after transplanting

Treatment	Pant height at different days after transplanting (DAT) (cm)					
	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT
Growing substrates (M)						
M_1	5.89	11.00a^z	16.72 a	20.00a	22.28 a	23.33a
M_2	6.28	10.71a	16.00 a	19.33 a	22.24 a	22.78 a
M_3	6.39	7.58 c	8.67 c	9.00 c	10.39 c	13.11 c
M_4	6.17	8.88 b	12.11 b	14.39 b	16.72 b	20.72 b
P	0.342	<0.001	<0.001	<0.001	<0.001	<0.001

^{z}Means with different letter is significantly different by Tukey's test at $P \leq 0.05$.
M_1 = 60% rice husk + 30% coconut coir + 10% vermicompost, M_2= 60% coconut coir+ 30% brocken brick + 10% vermicompost, M_3 = 60% sawdust + 30% brocken brick + 10% vermicompost, and M_4 = 60% ash + 30% brocken brick + 10% vermicompost. *P* represents the level of significance of ANOVA.

(1995) reported that the lack of bio-stability may cause severe volume loss resulting in compaction, reduction in air volume, readily available water, and porosity due to mineralization and also changes in gaseous phase composition due to carbon dioxide production. These changes may finally reduce the plant growth. Thus, the plant height in saw dust based growing media reduced drastically in the present experiment. On the other hand, carbonized rice husk is more sterile and have the ability to supply nutrient in some extent at the early stage of planting, but pH was higher compared to the other substrates. Meanwhile the pH and EC with other properties were more appropriate in coco-peat based growing media resulting higher height plant of lettuce.

Leaf length

The growth pattern of leaf length was almost similar to that of plant height (Table 2). The leaf length increased in increasing days until maturity. At 7 DAT, the highest leaf length (6.39 cm) was found in M_3 and the lowest leaf length (5.89 cm) was found in M_1. At 14 DAT, the highest leaf length (11 cm) was found in M_1 and the lowest leaf length (97.58 cm) was found in M_3. At 21 DAT, the maximum leaf length (16.72 cm) was found in M_1 and the minimum (8.67 cm) was found in M_3. At 28 DAT, the maximum leaf length (20.00 cm) was found in M_1 and the minimum (9.00 cm) was found in M_3. At 35 DAT, the supreme leaf length (22.28 cm) was found in M_1 and the shortest (10.39 cm) was found in M_3.At 42 DAT, the highest leaf length (23.33 cm) was found in M_1 and the lowest (13.11 cm) was found in M_3. The results revealed that the highest leaf length at all dates were found in plants grown in media mixture of 60% rice husk + 30% coconut coir + 10% vermicompost (M_1) which was statistically similar to that of media mixture of 60% coconut coir+ 30% brocken brick +10% vermicompost (M_2). Meanwhile the lowest leaf length at dates were observed in the plants grown in the media mixture of 60% sawdust + 30% brocken brick + 10% vermicompost (M_3). Michael and Lieth (2008) reported that an increase in total pore space will often decrease the water retention, increase oxygen transport and increase root penetration. These, in turn, will influence plant growth.

Leaf breath

Leaf breath of lettuce was not significantly affected by different growing substrates at 7 days after transplanting (Table 3) whereas it was significant at 14, 21, 28, 35 and 42 DAT due to different types of growing substrates mixture (Table 8). The leaf breath increased in increasing days until maturity. At 7 DAT, the widest leaf (3.24 cm) was found in M_3 and the narrowest (2.90 cm) was found in M_4. At 14 DAT, the widest leaf (6.41 cm) was found in M_1 and the narrowest (4.18 cm) was found in M_3. At 21 DAT, the broad leaf (8.76 cm) was found in M_1 and the narrowest leaf (4.37 cm) was found in M_3. At 28 DAT, the extensive leaf breath (11.33 cm) was found in M_1 and the narrowest (4.50 cm) was found in M_3. At 35 DAT,

Table 2. Effects of growing substrates on leaf length of lettuce at different days after transplanting

Treatment	Leaf length at different days after transplanting (DAT) (cm)					
	7 DAT	14DAT	21DAT	28DAT	35DAT	42DAT
Growing substrates (M)						
M_1	6.28	11.00a^z	16.72a	20.00a	20.72a	22.94a
M_2	5.89	10.71 a	16.00a	19.33a	20.72a	22.28a
M_3	6.39	7.58 c	8.67 c	9.00c	10.39c	10.94 c
M_4	6.17	8.86 b	12.11 b	14.39 b	16.72 b	18.56 b
P	0.342	<0.001	<0.001	<0.001	<0.001	<0.001

^{z}Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. M_1 = 60% rice husk + 30% coconut coir + 10% vermicompost, M_2= 60% coconut coir+ 30% brocken brick + 10% vermicompost, M_3 = 60% sawdust + 30% brocken brick + 10% vermicompost, and M_4 = 60% ash + 30% brocken brick + 10% vermicompost. *P* represents the level of significance of ANOVA.

Table 3. Effects of growing substrates on leaf breath of lettuce at different days after transplanting

Treatment	Leaf breath at different days after transplanting (DAT) (cm)					
	7DAT	14DAT	21DAT	28DAT	35DAT	42DAT
Growing Substrates (M)						
M_1	3.13	6.41a[z]	8.76a	11.33a	12.67a	16.83a
M_2	2.94	5.93a	7.89b	10.00b	11.67a	14.78a
M_3	3.12	4.18b	4.37c	4.50c	5.94c	6.94c
M_4	2.90	4.39b	8.17b	8.94b	9.50b	11.39b
P	0.700	<0.001	<0.001	<0.001	<0.001	<0.001

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$.

M_1 = 60% rice husk + 30% coconut coir + 10% vermicompost, M_2= 60% coconut coir+ 30% brocken brick + 10% vermicompost, M_3 = 60% sawdust + 30% brocken brick + 10% vermicompost, and M_4 = 60% ash + 30% brocken brick + 10% vermicompost. *P* represents the level of significance of ANOVA.

Table 4. Effects of growing substrates on number of leaf of lettuce at different days after transplanting

Treatment	Number of leaf at different days after transplanting (DAT) (cm)					
	7DAT	14DAT	21DAT	28DAT	35DAT	42DAT
Growing Substrates (M)						
M_1	5.33	6.89a[z]	9.44a	12.56a	14.11a	21.44 a
M_2	5.56	6.33ab	9.22a	12.89a	13.89a	18.44 b
M_3	5.00	5.89b	5.33b	8.56b	7.11c	8.11 d
M_4	5.33	6.11b	8.78a	9.00b	10.33b	15.67 c
P	0.158	<0.001	<0.001	<0.001	<0.001	<0.001

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$.

M_1 = 60% rice husk + 30% coconut coir + 10% vermicompost, M_2= 60% coconut coir+ 30% brocken brick + 10% vermicompost, M_3 = 60% sawdust + 30% brocken brick + 10% vermicompost, and M_4 = 60% ash + 30% brocken brick + 10% vermicompost. *P* represents the level of significance of ANOVA.

the widest leaf (12.67 cm) was found in M_2 and the narrowest (5.94 cm) was found in M_3. At 42 DAT, the widest leaf (16.83 cm) was found in M_1 and the narrowest (6.94 cm) was found in M_3. The results revealed that the maximum leaf breath at all dates were found in plants grown in media mixture of 60% rice husk + 30% coconut coir + 10% vermicompost (M_1) which was statistically similar to that of media mixture of 60% coconut coir+ 30% brocken brick + 10% vermicompost (M_2). Meanwhile the minimum leaf breath at all dates were observed in the plants grown in the media mixture of 60% sawdust + 30% brocken brick + 10% vermicompost (M_3). These might be due to improve physical and chemical properties of M_1 and M_2 that were discussed earlier. Lemaire (1995) reported that the lack of biostability may cause severe volume loss resulting in compaction, reduction in air volume, readily available water, and porosity due to mineralization and also changes in gaseous phase composition due to carbon dioxide production. These changes may finally reduce the plant growth (Lemaire 1995). Thus, the leaf breath in saw dust based growing media reduced drastically in the present experiment. On the other hand, carbonized rice husk is more sterile and have the ability to supply nutrient in some extent at the early stage of planting, but pH was higher compared to the other substrates. Meanwhile the pH and EC with other properties were more appropriate in coco-peat based growing media resulting higher height plant of lettuce.

Number of leaves of lettuce

Number of leaf lettuce was not significantly affected by different growing substrates at 7 days after transplanting (Table 4). But it was significant at 14, 21, 28, 35 and 42 DAT due to different types of growing substrates mixture (Table 4). At 7 DAT, the highest number of leaf lettuce (5.56 cm) was found in M_2 and the lowest number of leaf lettuce (5.00 cm) was found in M_3. At 14 DAT, the maximum number of leaf lettuce (6.89 cm) was found in M_1 and the least number of leaf lettuce (5.89 cm) was found in M_3. At 21 DAT, the largest number of leaf lettuce (9.44 cm) was found in M_1 and the minimum (5.33 cm) was found in M_3. At 28 DAT, the extensive number of leaf lettuce (12.89 cm) was found in M_2 and the minimum number of leaf lettuce (8.56 cm) was found in M_3. At 35 DAT, the highest number of leaf lettuce (14.11 cm) was found in M_1 and the lowest number of leaf lettuce (7.11 cm) was found in M_3. At 42 DAT, the maximum number of leaf lettuce (21.44 cm) was found in M_1 and the minimum number of leaf lettuce (8.11 cm) was found in M_3.

The results revealed that the highest number of leaf lettuce at all dates were found in plants grown in media mixture of 60% rice husk + 30% coconut coir + 10% vermicompost (M_1) which was statistically similar to that of media mixture of 60% coconut coir+ 30% brocken brick + 10% vermicompost (M_2). Meanwhile the lowest number of leaf lettuce at all dates were observed in the

Table 5. Effects of growing substrates on fresh weight of lettuce

Treatment	Fresh weight (FW) per pant at transplanting time (g)	Fresh weight (FW) per pant at harvesting time (g)			
		Total	Leaf	Stem	Root
Growing Substrates (M)					
M_1	1.5422a[z]	92.49 a	71.91 a	8.89 a	11.69 a
M_2	1.0334b	75.56 b	65.33 b	6.09 c	4.14 c
M_3	0.4060c	50.69 d	46.89 d	2.58 d	1.22 d
M_4	0.3433c	68.88 c	56.27 c	8.33 b	4.28 b
P	<0.001	<0.001	<0.001	<0.001	<0.001

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$.

M_1 = 60% rice husk + 30% coconut coir + 10% vermicompost, M_2= 60% coconut coir+ 30% brocken brick + 10% vermicompost, M_3 = 60% sawdust + 30% brocken brick + 10% vermicompost, and M_4=60% ash + 30% brocken brick + 10% vermicompost. *P* represents the level of significance of ANOVA.

plants grown in the media mixture of 60% sawdust + 30% brocken brick + 10% vermicompost (M_3). These might be due to improve physical and chemical properties of M_1 and M_2 that were discussed earlier. Meanwhile the pH and EC with other properties were more appropriate in coco-peat based growing media resulting higher leaf number of lettuce.

Fresh weight of lettuce

Marketable quality of lettuce is determined mainly by plant size, which depends on fresh weight. Significant difference of fresh weight at transplanting time are differed among four treatments. At the time of transplantation of lettuce plant, it was noticed that lettuce gave highest fresh weight (1.5422 g plant-1) in M1 which was similar to M2 (1.0334 g plant-1) and the lowest fresh weight (0.3433 g plant-1) was found in M4. This might be due to the genetic inherent characteristics of lettuce cultivars (Table 5). On the other hand, at the harvesting time, total fresh weight found highest in M1 (92.49 g plant-1) and lower fresh weight found (50.69 g plant-1) in M3. Highest fresh weight of leaf was found (71.91 g plant-1) in M1 and the lowest leaf fresh weight (46.89 g plant-1) found in M3. Fresh weight of stem found highest (8.89 g plant-1) in M1 and the lowest fresh weight of stem (2.58 g/plant) found in M3. In case of root, highest fresh weight (11.69 g plant-1) found in M1 and lowest fresh weight (1.22 g plant-1) found in M3. These might be due to improve physical and chemical properties of M1 that were discussed earlier. Rahman et al. (2017b) reported that fresh weight of lettuce increased with increasing the volume of nutrient applied. Michael and Lieth (2008) reported that an increased in total pore space will often decrease the water retention, increase oxygen transport and increase root penetration. These, in turn, will influence plant growth. Thus, the fresh weight in saw dust based growing media reduced drastically in the present experiment. On the other hand, carbonized rice husk is more sterile and have the ability to supply nutrient in some extent at the early stage of planting. Meanwhile, pH and EC with other properties were more appropriate in rice husk based growing media resulting higher fresh weight of lettuce. It can improve the total marketable fresh weight of lettuce. Andriolo et al. (2005) also stated that EC levels above 2.0 and 2.6 dS m^{-1} reduced fresh yield and plant growth, respectively in lettuce.

Dry weight of lettuce

Plant dry weights of lettuce were varied significantly by four treatments (Table 6). The highest dry weights (0.3433 g/plant) at transplanting time were found in M_1 and the lowest dry weights (0.01624 g/plant) found in M_3. Meanwhile, at the harvesting time, total dry weight

Table 6. Effects of growing substrates on dry weight of lettuce

Treatment	Dry weight (DW) per pant at transplanting time (g)	Dry weight (DW) per pant at harvesting time (g)			
		Total	Leaf	Stem	Root
Growing Substrates (M)					
M_1	0.3433a[z]	4.6245a	3.5955a	0.4445a	0.5845a
M_2	0.07711b	3.778b	3.2665b	0.3045b	0.207b
M_3	0.01624c	2.0276c	1.8756c	0.1032c	0.0488c
M_4	0.05167b	2.7552b	2.2508b	0.3332b	0.1712b
P	<0.001	<0.001	<0.001	<0.001	<0.001

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$.

M_1 = 60% rice husk + 30% coconut coir + 10% vermicompost, M_2= 60% coconut coir+ 30% brocken brick + 10% vermicompost, M_3 = 60% sawdust + 30% brocken brick + 10% vermicompost, and M_4 = 60% ash + 30% brocken brick + 10% vermicompost. *P* represents the level of significance of ANOVA.

found highest in M_1 and it was (4.6245 g/plant), the lowest dry weight found (2.0276 g/plant) in M_3. Weight of dry leaf found highest (3.5955 g/plant) in M_1 and the lowest leaf dry weight (1.8756 g/plant) found in M_3. Dry weight of stem found greatest (0.4445 g/plant) in M_1 and the lowest dry weight of stem (0.1032g/plant) found in M_3. In case of root, higher dry weight (0.5845 g/plant) found in M_1 and lowest dry weight (0.0488 g/plant) found in M_3. These might be due to improve physical and chemical properties of M_1 that were discussed earlier. Michael and Lieth (2008) reported that an increase in total pore space will often decrease the water retention, increase oxygen transport and increase root penetration. These, in turn, will Influence plant growth. Thus, the plant height in saw dust based growing media reduced drastically in the present experiment. On the other hand, carbonized rice husk is more sterile and have the ability to supply nutrient in some extent at the early stage of planting. Meanwhile the pH and EC with other properties were more appropriate in rice husk based growing media resulting higher plant growth of lettuce.

CONCLUSIONS

Higher fresh weight and other vegetative growth parameters of lettuce were found in M_1 treatment in aggregate hydroponic system. Therefore, it can be concluded that lettuce cultivars' Legacy' can be grown in rice husk based growing media at the ratio of 60% rice husk, 30% coconut coir and 10% vermicompost in an aggregate soilless culture in Bangladesh.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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