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The effects of irrigation timing on growth, yield, and physiological traits of hydroponic lettuce

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ABSTRACT

Crop-specific timing of irrigation is necessary to conserve irrigation water and improve yield of vegetables. Therefore, the experiment was conducted to identify the optimum irrigation timings for hydroponic lettuce plants. Three nutrient solution timings, T_1(once a day at 0900 hours), T_2(once on alternative days at 0900 hours), and T_3(once at two-day intervals), and three varieties, 'Legacy' (V_1), 'Red fire' (V_2), and 'Green wave' (V_3) were evaluated. Growth and yield parameters, including number of leaves, leaf length, leaf diameter, and fresh weight of leaves, and growth parameters, including leaf area (LA), leaf area ratio (LAR), leaf mass ratio (LMR), root weight ratio (RWR), relative growth rate (RGR), and net assimilation rate (NAR) were determined. The values of growth parameters were the highest for T_1. The highest and lowest NAR and RGR values were obtained for T_1 and T_3, respectively. The values of most growth traits, including fresh weight, NAR, and RGR were higher for V_1 than other varieties. T_1 provides high yield with comparatively less irrigation water and nutrient solution so it can be used to culture lettuce using aggregate hydroponics as.

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is an economically important vegetable crop worldwide (Palmer et al. 2005). It is cultivated using intensive farming in open fields as well as in greenhouses (Bartzas et al. 2015). Irrigation is necessary to ensure stable yields and high quality of lettuce grown in greenhouses (Rahman et al. 2012). Crop-specific irrigation timings that save water and do not negatively affect crop productivity need to be developed for sustainable crop cultivation (Quamruzzaman et al. 2017). Deficit irrigation methods, namely regulated deficit irrigation and partial root zone drying have been successfully used to improve irrigation water use efficiency in various crop species (Kirda et al. 2004; Van Hooijdonk et al. 2004) but the timing of nutrient application timing on lettuce grown in soilless culture has not yet been studied. Research has been conducted to determine the influence of irrigation timing on field-grown sweet pepper (Russo 2011). Knowledge of the effects of irrigation timing on vegetable production in soilless culture could help to improve crop yield and quality of the products. The timing of nutrient solution delivery can affect water availability to plants, and directly affect yield, quality, and production costs. Thus, an understanding of the timing of nutrient solution is important to achieve sustainable agriculture. Sustainable agricultural development depends on sound irrigation and water management, the main aim of which is to satisfy the crop's water requirement, and to maintain good soil aeration (McNiesh and Welch 1985). Therefore, in application timing of nutrient solution could result in serious yield reduction. Furthermore, over-irrigation and prolonged soil saturation can cause root rot or disease in plant roots. However, differences in irrigation timing and volume could have an effect on the growth and yield of lettuce plants. Therefore, this experiment was conducted to determine the optimal timing and volume for nutrient solution application to lettuce plants.

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MATERIALS AND METHODS

Experimental site and plant materials

A semi-greenhouse experiment was conducted in the Horticulture Farm at the Sher-e-Bangla Agricultural University, Dhaka from September 2016 to March 2017. Three lettuce cultivars, *viz.*, 'Legacy', 'Red fire', and 'Green wave' were used in this experiment.

Experimental design and treatments

A randomized complete block design with 3 × 3 factorial treatments and three replications were used in this study. The two factors of this experiment were three nutrient solution application timings, *viz.*, T_1 (once a day at 0900 hours), T_2 (once on alternative days at 0900 hours), and T_3 (once at two days interval at 0900 hours), and three varieties, *viz.*, 'Legacy' (V_1), 'Red fire' (V_2), and 'Green wave' (V_3).

Growth Environment

Twenty-seven plastic crates of 25L pots were used for culturing the plants. Each pot was filled with a mixture of coco peat, broken bricks, and vermiculite in a ratio of 60:30:10 (v/v), respectively. Coco peat was soaked in a big bowl for 24 h. It was washed with water and spread in a polythene sheet for 3 h and mixed with broken bricks and vermiculite. The experiment was conducted in a semi-greenhouse (not controlled environment, i.e. temperature, humidity etc) under intensive care. Half strength of Rahman and Inden (Rahman and Inden, 2012) solution was used in this experiment. The concentrations of the nutrients, *viz.*, NO_3-N, P, K, Ca, Mg, and S were 17.05, 7.86, 8.94, 9.95, 6.0, and 6.0 meq•L^{-1}, respectively. The concentrations of the micronutrients, *viz.*, Fe, B, Zn, Cu, Mo, and Mn were 3.0, 0.5, 0.1, 0.03, 0.025, and 1.0 mg•L^{-1}, respectively. The timing of the nutrient solution's application depended on the treatment and the same volume of nutrient solution was applied. An ultra-drip irrigation tube and electric timers were used for maintaining the volume and time of nutrient application. The pH and electrical conductivity (EC) were maintained at approximately 6.0 and 2.5 dS/cm, respectively in the nutrient solutions. Two-week-old lettuce seedlings were transplanted in the pots. Three plants were considered as an experimental unit in each crate.

Harvesting

The crop was harvested at 42 days after transplanting (DAT). Crop was harvested from each crate by carefully uprooting the plants with hands. The growth media and fibrous roots adhering to the roots were removed and cleaned.

Data collection

Growth and yield parameters, *viz.,* number of leaves, leaf length, leaf diameter, and fresh weight of leaves of lettuce were measured from 0 to 42 DAT at 7-day intervals. The physiological growth parameters *viz.,* leaf area (LA), leaf area ratio (LAR), leaf mass ratio (LMR), root weight ratio (RWR), relative growth rate (RGR), and net assimilation rate (NAR) were also determined. The parameters were measured according to Rahman and Inden (2012b), as described below.

$$LAR = \frac{LA}{PDW} \quad (1),$$

Where LAR = leaf area ratio, LA = Leaf area (cm^2), PDW = plant dry weight (g).

$$LMR = \frac{LDW}{PDW} \quad (2),$$

Where LMR = leaf mass ratio, LDW = leaf dry weight (g).

$$RWR = \frac{RDW}{PDW} \quad (3),$$

Where RWR = root weight ratio, RDW = root dry weight (g).

$$RGR = \frac{PDW_1 - PDW_0}{(t_1 - t_0) \times PDW_0} \quad (4),$$

Where t = time, subscripts 0 and 1 refer to the transplanting and final harvest (days), respectively.

$$NAR = \frac{RGR}{LAR} \quad (5)$$

Statistical analysis of data

Data from the two trials were combined and analyzed by one-way analysis of variance (ANOVA) using SPSS version 19.0, and differences among the means were determined by Tukey's test at $P \leq 0.05$.

RESULTS AND DISCUSSIONS

Vegetative growth of lettuce

Significant differences were observed in the plants' heights as a result of irrigation at 7, 14, 21, 28, 35, and 42 DAT (Table 1). Results showed that T_1 treatment produced the tallest plants and the heights were statistically similar to those obtained for T_2 at 7, 14, 21, 28, 35, and 42 DAT, while T_3 produced the shortest plants at all time of irrigation. This might be because of treatment T_1 resulting in the maximum vegetative growth, because irrigation helped in higher vegetative growth (Rahman et al. 2012). Niu et al. (2006) reported that photosynthesis, transpiration (E), and stomatal conductance (gs) of some bedding plants were reduced when the moisture content in the growth substrate was decreased. Furthermore, Bozkurt et al. (2009) found that the irrigation level influenced the height of the lettuce plant. The lettuce plant's height was also significantly affected by water

Table 1. Effects of irrigation timing and variety on plant height of lettuce

Treatment	Pant height at different days after transplanting (DAT) (cm)					
	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT
Timing (T)						
T_1	6.63a[z]	10.33 a	13.83 a	16.75 a	18.63 a	22.04 a
T_2	6.13ab	9.03 b	13.88 a	15.79 ab	17.71 b	19.92 a
T_3	5.79b	9.24 b	12.42 b	14.50 b	16.13 c	18.79 b
Variety (V)						
V_1	6.39a[z]	10.71 a	16.00 a	19.33 a	22.28 a	22.78 a
V_2	5.89	7.58 c	8.67 c	9.00 c	10.39 c	13.11 c
V_3	6.17	8.88 b	12.11 b	14.39 b	16.72 b	20.72 b
Level of significance (*P*)						
T	0.008	<0.001	0.002	0.003	<0.001	<0.001
V	0.342	<0.001	<0.001	<0.001	<0.001	<0.001
T × V	0.999	0.033	0.001	<0.001	<0.001	<0.001

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of two-way ANOVA. T_2 = once a day at 0900 HR; T_2 = Once at alternative days at 0900 HR and; and T_3 = Once at two days interval at 0900 HR. V_1 = 'Legacy', V_2 = 'Red fire', andV_3= 'Green wave'.

deficiency (Acar et al. 2008). The results are consistent with these findings.

The vegetative growth observed for T_2 was statistically similar to that observed for treatment T_1 with less water and nutrient supply. This could reduce the volume of irrigation water as well as nutrient solution, thereby reducing the cost of lettuce production.

There were differences among the heights of the lettuce plants of different varieties (Table 1). The heights of lettuce plants tended to increase with increasing the days of planting. V_1 plants were the highest, while V_2 plants were the smallest at 7, 14, 21, 28, 35, and 42 DAT. This might be because of genetic composition of V_1.

In the case of interaction effect of time and variety (TV), significant differences of plant height were observed at all dates except at 7 DAT (Table 1).

Irrigation timing had a significant effect on the leaf length (Table 2). Treatment of T_1 resulted in the longest leaves at all sampling dates, except at 21 DAT and 28 DAT. At 21 DAT and 28 DAT, leaves from T_2 were the longest. Furthermore, T_3 resulted in the shortest lettuce leaves at all time-points. These results indicate that a considerable reduction in water and nutrient supply has an adverse effect on leaf length in T_3. Rahman et al. (2012) observed that three times of nutrient supply resultant the higher photosynthetic rates in sweet pepper ultimately affected yield. Our results are consistent with their findings.

Leaf lengths of V_1 were significantly higher

Table 2. Effects of irrigation timing and variety on leaf length of lettuce

Treatment	Leaf length at different days after transplanting (DAT) (cm)					
	7 DAT	14DAT	21DAT	28DAT	35DAT	42DAT
Timing (T)						
T_1	6.62a[z]	10.33a	13.83a	15.79ab	19.92a	19.42a
T_2	6.12ab	9.24b	13.88a	16.75a	17.63b	18.71ab
T_3	5.79b	8.02c	10.42c	12.50c	14.01c	16.08c
Variety (V)						
V_1	6.39a[z]	11.00a	16.72a	20.00a	22.94a	20.72a
V_2	6.28	7.58c	8.67c	9.00c	10.39c	10.94c
V_3	6.17	8.86b	12.11b	14.39b	16.72b	18.56b
Level of significance(p)						
T	0.008	<0.001	0.002	0.003	<0.001	<0.001
V	0.342	<0.001	<0.001	<0.001	<0.001	<0.001
T x V	0.999	0.001	0.001	<0.001	<0.001	0.001

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of two-way ANOVA. T_2 = once a day at 0900 HR; T_2 = Once at alternative days at 0900 HR and; and T_3 = Once at two days interval at 0900 HR. V_1 = 'Legacy', V_2 = 'Red fire', andV_3= 'Green wave'.

Table 3. Effects of irrigation timing and variety on leaf breadth of lettuce

Treatment	Leaf breath at different days after transplanting (DAT) (cm)					
	7DAT	14DAT	21DAT	28DAT	35DAT	42DAT
Irrigation Timing (T)						
T_1	3.13a[z]	5.09 a	7.79 a	9.83 a	11.08a	12.25a
T_2	3.02	5.67 a	7.48 a	9.42 a	10.21a	11.70a
T_3	3.02	4.93 b	6.32 b	7.58 b	9.41b	10.50b
Variety (V)						
V_1	3.24a[z]	4.18b	8.76a	11.33a	12.67a	14.78a
V_2	3.13	4.39b	4.46 c	4.50c	4.94 c	6.94c
V_3	2.90	5.93a	7.89b	9.94b	10.36 b	11.39b
Level of significance (p)						
V	0.700	<0.001	<0.001	<0.001	<0.001	<0.001
T	0.895	<0.001	<0.001	<0.001	0.101	0.195
T x V	0.704	<0.001	<0.001	<0.001	0.001	0.601

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of two-way ANOVA. T_2 = once a day at 0900 HR; T_2 = Once at alternative days at 0900 HR and; and T_3 = Once at two days interval at 0900 HR. V_1 = 'Legacy', V_2 = 'Red fire', andV_3= 'Green wave'.

than other varieties except at 7 DAT (Table 2). Moreover, V_2 produced the shortest leaves at all time of irrigation except 7 DAT. This result could be attributed to the genetic variations among the varieties.

In the case of combined effect of TV, significant variation of leaf length was observed at all times except 7 DAT (Table 2).

Treatment T_1 resulted in the broadest leaves at all sampling times except at 14 DAT (Table 3), the results were statistically similar to those obtained from T_2. Appropriate irrigation and nutrient supply from treatment T_1 could have resulted in broader lettuce leaves.

A significantly broadest leaf breath was recorded from different varieties at all time-points except at 7 DAT (Table 3). V_3 produced the broadest leaf at 14 DAT, while for the rest of the time of irrigation V_1 produced the broadest leaf. This might be because of the genetic variations among the varieties.

In the case of interaction effect of TV, significant variation of leaf breadth was observed at all times except at 7 DAT and 42 DAT (Table 3).

Statistically significant differences were observed in the total number of leaves per plant after different irrigation timings (Table 4). T_1 produced the highest number of leaves at all sampling times; the results were statistically similar to those obtained for treatment T_2. This might be because of the optimal supply of irrigation water containing the required nutrient solution. T_3 produced the minimum number of leaves as a result of a reduction in irrigation timing as well as nutrient solution (Table 4). Acar et al. (2009) and Bozkurt and Mansuroglu (2011) found that the volume of water significantly affected the number of lettuce leaves. Our results are consistent with their findings.

There were significant differences in the number of leaves of different varieties at all time of irrigation except at 7 DAT (Table 4). The highest leaf number was recorded for V_1 at all time of irrigation except at 14DAT; V_3 produced the highest leaf number at 14 DAT. This might be

Table 4. Effects of irrigation timing and variety on number of leaf of lettuce

Treatment	Number of leaf at different days after transplanting (DAT) (cm)					
	7DAT	14DAT	21DAT	28DAT	35DAT	42DAT
Irrigation Timing (T)						
T_1	5.50a[z]	6.75a[z]	8.92a	11.58a	12.83a	16.66a
T_2	5.17	6.17b	8.75a	10.92a	12.08a	16.33a
T_3	5.25	6.00b	6.92b	8.75b	10.17b	14.75b
Variety (V)						
V_1	5.56a[z]	6.11b[z]	9.22a	12.89a	14.11a	18.44 a
V_2	5.00	6.33ab	7.33ab	8.56b	10.11b	13.11 b
V_3	5.33	6.89a	8.78b	9.00b	10.33b	15.67 b
Level of significance (p)						
T	0.256	0.002	<0.001	<0.001	0.005	<0.001
V	0.158	0.001	<0.001	<0.001	<0.001	<0.001
T x V	0.448	0.336	0.001	<0.001	0.001	<0.001

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of two-way ANOVA. T_2 = once a day at 0900 HR; T_2 = Once at alternative days at 0900 HR and; and T_3 = Once at two days interval at 0900 HR. V_1 = 'Legacy', V_2 = 'Red fire', andV_3= 'Green wave'.

Table 5. Effects of irrigation timing and variety on fresh weight of lettuce

Treatment	Fresh weight (FW) per pant of lettuce (g) at transplanting time	Fresh weight (FW) per pant of lettuce at harvesting time			
		Total FW	FW of leaf	FW of stem	FW of root
Irrigation Timing (T)					
T_1	0.9312 a[z]	64.08 a	52.42 a	6.54 a	5.12 a
T_2	0.7124 b	57.40 b	46.54 b	5.97 b	4.89 b
T_3	0.8502 a	45.57 c	35.99 c	5.41 b	4.48 b
Varieties (V)					
V_1	1.5422 a[z]	69.88 a	56.27 a	8.33 a	5.28 a
V_2	0.4060 b	45.69 c	36.89 c	5.58 b	3.22 b
V_3	0.3433 c	56.56 b	45.33 b	7.09 c	4.14 b
Level of significance (p)					
T	<0.001	<0.001	0.008	<0.001	<0.001
V	<0.001	<0.001	<0.001	<0.001	<0.001
T x V	<0.001	<0.001	0.0043	0.001	<0.001

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of two-way ANOVA. T_2 = once a day at 0900 HR; T_2 = Once at alternative days at 0900 HR and; and T_3 = Once at two days interval at 0900 HR. V_1 = 'Legacy', V_2 = 'Red fire', andV_3= 'Green wave'.

because of the genetic variations among the varieties.

In the case of combined effect of TV, significant variation of number of leaf was observed at all time of irrigation except at 7 DAT and 14DAT (Table 4).

Fresh weight

Fresh weight was recorded at the end of the experiment at 42 DAT. The fresh weight of lettuce is considered to constitute its marketable yield. The total fresh weight and fresh weights of leaf, stem, and root per plant obtained for the different irrigation timings were significantly different (Table 5). The fresh weights of seedlings from T_1 were statistically similar to those of seedlings from T_3, but were higher than fresh weights of seedlings from T_2. The values of total fresh weigh and fresh weights of leaf, stem, and root per plant were the highest for T_1, and were statistically similar to those obtained for T_2; the lowest values were obtained for T_3. The reason for this could be that the vegetative growth of the plants was higher in T_1 than the other treatments. This finding also showed that the plant's fresh weight decreased when there was a reduction in the rate of irrigation and nutrient solution. Mansuroglu et al. (2010) reported that a full irrigation treatment resulted in the highest yields, while the lowest volume of water applied to lettuce plants resulted in minimal yields.

The highest and the lowest values of fresh weight were obtained for V_1 and V_2, respectively

Table 6. Main effects of irrigation timing and variety on dry weight of lettuce

Treatment	Dry weight (DW) per pant of lettuce (g) at transplanting time	Dry weight (DW) per pant of lettuce at harvesting time			
		Total DW	DW of leaf	DW of stem	DW of root
Irrigation Timing (T)					
T_1	0.04656a[z]	3.204 a	2.621 a	0.327 a	0.256 a
T_2	0.02849 b	2.296 b	1.861 b	0.238 b	0.195 b
T_3	0.03400 a	1.822 c	1.439 c	0.216 c	0.179 c
Variety (V)					
V_1	0.07711 a[z]	3.494 a	2.8135 a	0.416 a	0.264 a
V_2	0.01624 b	1.827 c	1.4756 c	0.223 c	0.128 c
V_3	0.01373 c	2.262 b	1.8132 b	0.283 b	0.165 b
Level of significance (p)					
T	<0.001	<0.001	<0.001	<0.001	0.001
V	<0.001	<0.001	<0.001	<0.001	<0.001
T× V	<0.001	<0.001	<0.001	0.001	<0.001

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of two-way ANOVA. T_2 = once a day at 0900 HR; T_2 = Once at alternative days at 0900 HR and; and T_3 = Once at two days interval at 0900 HR. V_1 = 'Legacy', V_2 = 'Red fire', andV_3= 'Green wave'.

Table 7. Maine effects of irrigation timing and variety on physiological traits of lettuce

Treatment	LA (cm^2)	LMR ($g\ g^{-1}$)	LAR ($cm^2\ g^{-1}$)	RWR ($g\ g^{-1}$)	NAR ($g\ cm^{-2}\ d^{-1}$)	RGR ($g\ g^{-1}\ d^{-1}$)
Irrigation Timing (T)						
T_1	345.01a^z	0.82a	107.681 a	0.07990012 c	0.0000085 a	0.00091 a
T_2	329.45 b	0.81a	121.711 a	0.08493031 b	0.0000065 a	0.00065 b
T_3	145.91	0.78b	80.0823b	0.09824369 a	0.0000054 b	0.00052 c
Variety (V)						
V_1	305.01a^z	0.90 a	87.29536 c	0.075558 a	0.00001140 a	0.00099 a
V_2	249.55c	0.81 b	136.59 a	0.070060 b	0.00000380 c	0.00052 c
V_3	281.61 b	0.80 b	124.496 b	0.072944 c	0.00000516 b	0.00064 b
Level of significance (p)						
T	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
T× V	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

^{z}Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of two-way ANOVA. T_2 = once a day at 0900 HR; T_2 = Once at alternative days at 0900 HR and; and T_3 = Once at two days interval at 0900 HR. V_1 = 'Legacy', V_2 = 'Red fire', and V_3= 'Green wave'.LA = leaf area, LAR = leaf area ratio, LMR = leaf mass ratio, RWR = root weight ratio, RGR = relative growth rate, and NAR = net assimilation rate

(Table 5); these differences could have resulted from the genetic variations among the varieties.

In the case of combined effect of TV, significant variation of fresh weight was observed at all time of irrigation (Table 5).

Dry weight

Irrigation timing had a significant impact on the dry weight of lettuce. The maximum dry weight was recorded for T_1 (Table 6). The highest values of total dry weight, and dry weights of leaf, stem and root per plant were obtained for T_1, which were statistically similar to those obtained for T_2, while the lowest were obtained for T_3. An optimal supply of irrigation water and nutrient in T_1 resulted in the maximum vegetative growth.

V_1 had the highest dry weight (Table 6); this might be because of the genetic variations among the varieties.

In the case of combined effect of TV, significant variation of dry weight was observed at all time of irrigation (Table 6).

Physiological growth traits

The growth parameters of lettuce were significantly influenced by irrigation timing and volume (Table 7). The results showed that the values of LA, LMR, NAR, and RGR were the highest for T_1, while the values of the traits were the lowest for T_3, except for RWR. The highest values of LAR and RWR were obtained for T_2 and T_3, respectively. Higher LA accelerates the production of metabolites. Prieto et al. (2007) stated that higher LA resulted in an increase in the plant's ability to intercept light. The values of LA and LMR were higher in the T_1, which decreased upon the reduction in irrigation timing and volume in treatments of T_2 and T_3. Results indicated that along with the decrease in irrigation timing and volume, the production of metabolites also decreased. In contrast, RWR increased in the reduction in irrigation water and nutrient supply.

The growth parameters of the different varieties differed significantly (Table 7). The values of LA, RWR, NAR, and RGR were the highest in V_1 compared to other varieties. Moreover, V_1 had the lowest LMR and LAR, while V_2 had the highest LMR and LAR; this might be because of the genetic variations among the varieties.

In the case of combined effect of TV, significant variation of physiological growth traits was observed at all time-points (Table 7).

CONCLUSION

In conclusion, the values obtained for all the growth parameters, including fresh weight, NAR, and RGR of lettuce for treatment of T_1 were higher than those obtained for the other treatments; results from T_1 were statistically similar to those obtained for treatment T_2. Moreover, result obtained for most growth traits, including fresh weight, NAR, and RGR were higher in V_1 than other varieties. Since T_1 provides high yield with comparatively less irrigation water and nutrient solution so it can be used to culture lettuce using aggregate hydroponics as.

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USE OF SALT INDUSTRIES BYPRODUCT AS AN ALTERNATIVE LIQUID FERTILIZER IN FLOATING HYDROPONIC LETTUCE IN BANGLADESH

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ABSTRACT

Salt industries byproduct is a less expensive fertilizer source. But without testing its effect on growth and yield, it may not be suitable as fertilizer. Therefore, a laboratory trial was conducted to evaluate vegetative growth, physiological growth traits and yield of lettuce cv. 'Lolorossa' by application of three salt industries byproduct concentrations at 0 (T_1), 0.5mL.L^{-1} (T_2) and 0.75 mL. L^{-1}(T_3) into ¾ strength Rahman and Inden (2012) nutrient solution. Plant height, number of leaf, leaf length, fresh weight, and physiological growth traits, viz., leaf area (LA), leaf mass ratio (LMR), leaf area ratio (LAR), root weight ratio (RWR),net assimilation rate (NAR) and relative growth rate (RGR) were observed. Results revealed that the maximum number of leaf, leaf breadth and fresh weight were found in salt industries byproduct at 0.5 mL·L^{-1} compared to the control. But the vegetative growth was negatively affected by the application of salt industries byproduct at 0.75mL·L^{-1}. Physiological growth straits were negatively affected with increasing rates of salt industries byproduct. It was further found that RGR, NAR, and their related components improved when 0.5 mL·L^{-1} salt industries byproduct was applied compared to the control in lettuce. It may be concluded that salt industries byproduct can be used as liquid fertilizer source in hydroponic lettuce culture.

KEYWORDS: Salt Industries Byproduct, Soilless Culture, Floating Hydroponics & Lettuce

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INTRODUCTION

Effects are on to reducing the production cost of agricultural crops. Salt industries by-product can reduce production cost as it contains many macronutrients, especially calcium (Ca^{2+}), magnesium (Mg^{2+}), and micronutrients. It contains sodium (Na^+) that may impose mild salinity, but it also contains some silicon (Si) that may minimize the negative effects of salinity. Bradbury and Ahmad (1990) and Liang *et al*. (1996) reported that Si minimized the adverse effects of salinity. Ca^{2+} plays a key role in plant growth and fruit development and is involved in many biochemical and physiological processes (Saure, 2005).

Lettuce (*Lactuca sativa* L.) is the most popular amongst the salad vegetable crops and it is grown in green houses to produce high-quality, colored during an extended season. The production costs can be reduced by reducing nutrition or using cheaper fertilizer sources. The problem with traditional soilless culture is that it relies on costly chemical fertilizers, but the use of salt industries byproduct may reduce this cost. Plant growth analysis can be performed to monitor changes in overall plant growth affected by the application of salt industries byproduct. The efficiency of salt industries byproduct can be defined in terms of variation in relative growth rate (RGR) and morphological plant traits were studied, which could be used to simplify RGR. More information is available on the effect of light in tensity (Bruggink, 1987; Bruggink and Heuvelink, 1987)and salinity (Villa-Castorena *et al*., 2003) on RGR and its components. But, there is no information on the relationship between RGR and growth-related traits due to the application of salt industries byproduct.

The antioxidant content of fruits and vegetables is becoming increasingly important for growers who want to satisfy the demand of consumers for products with a high content of health-promoting constituents. An increase in antioxidant content in fresh lettuce can be accomplished by improving crop production practices, e.g. selection of varieties rich in phytochemicals and optimization of plant nutrition and water supply (Lee *et al.*, 1995). Furthermore, salt-industries byproduct, as cheaper fertilizer alternative, may be used for improving the antioxidant content in leaves of lettuce as well as reducing production cost. Therefore, the present work was aimed to evaluate the effect of salt industries byproduct application on yield, physiological growth, and antioxidant content in lettuce.

MATERIALS AND METHODS

Experimental Site

Two repeated experiments were conducted in greenhouses and Central Laboratory at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The transplanting and final harvesting dates of the first trial (Expt. 1) were 25th January and 7th March 2015, and of the second trial (Expt. 2) were 1st November and 15th December 2015, respectively.

Experimental Material

Lettuce cv.'Lolorossa' was used for growing hydroponic system in the Laboratory and greenhouse. Seeds of lettuce were collected from the University of Miyazaki, Japan.

Experimental Environment

The seeds were sown in the media mixture of coco peat, brick broken and rice husk at the ratio of 6:2:2 (v/v) into the 20-mL plastic disposable pots. One-week-old seedlings were transferred in the floating hydroponic system (Figure 1). It was made by cork-sheet of 50-cm × 35-cm. Cork sheet box contained nutrient solution. Air pumps and air-stones were used in the box to maintain oxygen content in the nutrient solution. Twenty-one plastic pots with healthy seedlings were transferred in each box. The salt industries byproduct was applied as treatment at 7 days after transplanting. The crop was cultivated for 42 days. The pH and EC of ≌ 6.0 and ≌ 2.8 – 3.0 $dS\cdot m^{-1}$, respectively were maintained in the nutrient solution.

Experimental Design

Both the experiments were conducted in a complete randomized design with five replications. Three concentrations of salt industries byproduct (SIB) were considered as treatments, viz., T_1– 0 $mL\cdot L^{-1}$SIB + ¾ strength Rahmanand Inden (2012) as a standard, T_2 – 0.5$mL\cdot L^{-1}$SIB + ¾ strength Rahmanand Inden (2012), T_3 – 0.75$mL\cdot L^{-1}$SIB + ¾ strength Rahmanand Inden (2012). A ¾ strength Rahman and Inden (2012) continued to plants until 15 days of transferred to the hydroponic system. After that treatments were started. The standard nutrient solution was selected according to the findings of our previous experiments (Rahman et al., 2015) in the same greenhouse and same condition. The composition of salt industries byproduct was given in Table 1.

Data Collection

Data were collected on growth and yield contributing characters, viz, plant height, number of leaves, breadth of leaves, leaf length, fresh weight of plant, dry weight of plant, and physiological parameters, viz., leaf area (LA), leaf area ratio (LAR), leaf mass ratio (LMR), root weight ratio (RWR), relative growth rate (RGR), and net assimilation rate (NAR) for both the experiments. The parameters were measured as described below:

$$\mathrm{LAR} = \frac{\mathrm{LA}}{\mathrm{PDW}} \quad (1)$$

Where, LAR = leaf area ratio, LA = Leaf area (cm^2), PDW = plant dry weight (g).

$$\mathrm{LMR} = \frac{\mathrm{LDW}}{\mathrm{PDW}} \quad (2)$$

Where, LMR = leaf mass ratio, LDW = leaf dry weight (g).

$$\mathrm{RWR} = \frac{\mathrm{RDW}}{\mathrm{PDW}} \quad (3)$$

Where, RWR = root weight ratio, RDW = root dry weight (g).

$$\mathrm{RGR} = \frac{\mathrm{PDW}_1 - \mathrm{PDW}_0}{(\mathrm{t}_1 - \mathrm{t}_0) \times \mathrm{PDW}_0} \quad (4)$$

Where, t = time. Subscripts 0 and 1 refer to the transplanting and final harvest (days), respectively.

$$\mathrm{NAR} = \frac{\mathrm{RGR}}{\mathrm{LAR}} \quad (5)$$

Statistical analysis of data: Data of the two trials were combined and analyzed by one-way analysis of varience (ANOVA) using SPSS version 19.0 and differences among the means were determined by using Tukey's test at $P \leq 0.05$.

RESULTS AND DISCUSSIONS

Plant Height: Two trials combined data for plant height of lettuce are shown in Table 2. Significant difference in plant height was found among the three concentrations of the salt industries byproduct application (Table 2). The longest plants were found in the control which was similar to that of T_2 and the shortest plant was found in T_3. The finding showed that plant height decreased with the increasing rate of salt industries byproduct. This might be due to the fact that salt industries byproduct contains some extent of Na^+ that might have imposed salinity. Furthermore, plant height was not adversely affected by salt industries byproduct at 0.5 $mL \cdot L^{-1}$. The mechanism for improvement of plant height due to application of salt industries byproduct at 0.5 $mL \cdot L^{-1}$ is not clear, but the positive impact of salt industries byproduct is due to the presence of rather high amounts of Ca^{2+} and Si, which might have contributed to reduce Na^+ absorption sites. Bradbury and Ahmad (1990) and Liang *et al.* (1996) reported that Si minimized the effects of salinity in *Prosopisjuliflora* and barley, respectively. Calcium sulfate counteracted the toxic effect of NaCl, resulting in greater plant height and leaf number of salt treated *Leucaenaleucocephala* plant (Hansen and Munns, 1988). Salt industries byproduct contained a higher amount of Ca^{2+} which may able to counteract the toxic effects of Na^+ when salt industries byproduct applied at the rate of 0.5 $mL \cdot L^{-1}$.

Number of Leaves per Plant*:* Two trials combined data for number of leaves per plant of lettuce are shown in Table 2.Significant difference in number of leaves per plant was found among the three concentrations of the salt industries byproduct application (Table 2). The maximum number of leaves was found in salt industries byproduct at 0.5 $mL \cdot L^{-1}$which was similar to the control and the minimum was found in T_3. The finding showed that number of leaves per plant decreased with increasing rate of salt industries byproduct. The reason might be same which was discussed in case of plant height. But the interesting finding was the higher number of leaves in salt industries byproduct at 0.5 $mL \cdot L^{-1}$ and it was decreased at 0.75 $mL \cdot L^{-1}$. This might be due to Ca^{2+} and Si content in salt industries byproduct at 0.5 $mL \cdot L^{-1}$ that can improve growth. But higher amount of salt industries byproduct at 0.75 $mL \cdot L^{-1}$ can impose more salt stress to the plant that can reduce growth.

Leaf Breadth: Two trials combined data for leaf breadth of lettuce are shown in Table 2.Significant difference in leaf breadth was found among the three concentration of the salt industries byproduct application (Table 2). The maximum leaf breadth was found in salt industries byproduct at 0.5 $mL \cdot L^{-1}$which was similar to the control and the minimum was found in T_3. The finding showed that number of leaves per plant decreased with increasing rate of salt industries byproduct. The reason might be same which was discussed in case of plant height. Andriolo *et al.* (2005) stated that lettuce growth was affected by different strength of salinity in the nutrient solution in lettuce. The present finding was also consisted with the findings of Andriolo *et al*. (2005). But the interesting finding was the higher number of leaves in salt industries byproduct at 0.5 $mL \cdot L^{-1}$ and it was decreased at 0.75 $mL \cdot L^{-1}$. This might be due to Ca^{2+} and Si content in salt industries byproduct at 0.5 $mL \cdot L^{-1}$ that can improve growth. But higher amount of salt industries byproduct at 0.75 $mL \cdot L^{-1}$ can impose more salt stress to the plant that can reduce growth.

Leaf Length: Two trials combined data for leaf length of lettuce are shown in Table 2 and Figure 2. The leaf length was not affected by treatments (Table 2). However, the maximum leaf length was found in the control which was similar to that of T_2 and the minimum was found in T_3. The finding showed that leaf length decreased with increasing rate of salt industries byproduct.

Fresh Weight: Two trials combined data for fresh weight of lettuce are shown in Table 2 and Figure 2. Marketable quality of lettuce is determined mainly by plant size, which depends on fresh weight. Fresh weight per plant was significantly varied by the concentration of salt industries byproduct application (Table 2 and Figure 3). The highest yield was found at salt industries byproduct when applied at 0.5 $mL \cdot L^{-1}$ and the lowest was found at 0.75 $mL \cdot L^{-1}$. The finding showed that plant fresh weight decreased with increasing rate of salt industries byproduct. In fact, this might be due to higher number of leaf and leaf bread by application of salt industries byproduct at 0.5 $mL \cdot L^{-1}$. Andriolo *et al.* (2005) also stated that EC levels above 2.6 dS m^{-1} reduce fresh yield and plant growth in lettuce. In the present experiment, EC level of T_3 was higher than that of 2.6 dS m^{-1} and it reduced fresh weight in lettuce by application of salt industries byproduct at 0.75 $mL \cdot L^{-1}$. Furthermore, Stamatakis *et al.* (2003) found a positive effect of Si addition to the nutrient solution under saline condition in tomato fruit yield and Alexander and Clough (1998) also observed that marketable yield of pepper increased due to increased Ca^{2+}. Similar result was observed in salt industries byproduct at 0.5 $mL \cdot L^{-1}$in this study. Because, salt industries byproduct contains Ca^{2+} and Si that might have a positive effect on fresh weight in lettuce.

Plant Dry Weight: Two trials combined data for plant dry weight of lettuce are shown in Table 3. Plant dry weights of lettuce significantly varied by salt industries byproduct rates. The highest dry weights of leaf and root were found in salt industries byproduct at 0.5 $mL \cdot L^{-1}$compared to the control. Meanwhile, dry weights of plants drastically decreased at0.75 mL·L^{-1}. This might be due to salt industries byproduct at0.5 mL·L^{-1}containing higher Ca^{2+} compared to the control, which contributed to higher dry weights. On the contrary, salt industries byproduct at0.75 mL·L^{-1}contains the highest amount of Ca^{2+} compared to the other treatments, but it might have salinity stress that caused poor dry weights. Epstein and Bloom (2005) reported that Ca^{2+} increased the root dry weight and calcium content in plant tissues. Bar-Tal *et al.* (2001) found that the shoot and root dry weights decreased with increasing Ca^{2+} in sweet pepper. The present findings consisted with the other findings.

Growth Analysis: Two trials combined data for plant growth analysis of lettuce are shown in Table 4. Growth parameters varied significantly by salt industries byproduct rates. Results revealed that LA, LMR, NAR, and RGR increased at 0.5 mL·L^{-1}salt industries byproduct compared to the control, but these traits drastically reduced at 0.75 mL·L^{-1}salt industries byproduct. On the contrary, LAR was the lowest in salt industries byproduct at 0.5 mL·L^{-1} and decreasing trend of RWR was found with increasing rate of salt industries byproduct. Higher LA is one of the important criteria for producing higher metabolites. Prieto *et al.* (2007) reported that increased LA gave the plants an increased ability to intercept light. We found higher LA, and LMR due to application of salt industries byproduct at 0.5 mL·L^{-1} that may have the ability to produce higher metabolites in lettuce. A decreased LAR was found by Starck (1983) in tomato, which agreed with our findings due to application of salt industries byproduct at 0.5 mL·L^{-1}in lettuce. The plant growth analyses data suggested that salt industries byproduct at 0.5 mL·L^{-1} provided better nutrition to the plants, followed by the control. This was most relevant in higher RGR and NAR due to application of salt industries byproduct at 0.5 mL·L^{-1}. But salt industries byproduct at 0.75 mL·L^{-1} may have mild water stress due to salinity that gave the lower growth in lettuce. RWR suggested that mild stress might have been occurred when salt industries byproduct applied at 0.75 mL·L^{-1}and it may have been responsible for the changes in plant growth affecting the allocation of resources between the root system and the rest of the plant. However, plant growth parameters indicated that application of salt industries byproduct at 0.5 mL·L^{-1} supported a higher level of plant growth.

CONCLUSIONS

It was found that growth, fresh marketable yield and physiological growth traits were affected by different concentrations of salt industries byproduct. The maximum number of leaf, leaf breadth and fresh weight were found in salt industries byproduct at 0.5 mL·L^{-1}.Similarly, RGR, NAR, and their related components also improved when 0.5 mL·L^{-1} salt industries byproduct was applied compared to the control. But all of these traits were lower at 0.75 mL·L^{-1} salt industries byproduct. Therefore, salt industries byproduct can be applied as liquid fertilizer source in hydroponic lettuce production. This hypothesis should be tested by more experiments and other aspect of hydroponic lettuce growth by using salt industries by product addition that will be addressed in our next experiments. The present study indicates that the application of salt industries byproduct has positive and also negative impact on hydroponic lettuce. Results revealed that the maximum number of leaf, leaf breadth and fresh weight were found in salt industries byproduct compared to the control. But the vegetative growth was negatively affected by the application of salt industries byproduct. Meanwhile, physiological growth straits were negatively affected with increasing rates of salt industries byproduct. Results revealed that RGR, NAR, and their related components improved salt industries byproduct was applied compared to the control in lettuce. It can be suggested that salt industries byproduct can be used as liquid fertilizer source in hydroponic lettuce culture in Bangladesh.

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APPENDICES

Table 1: Composition of Salt Industries Byproduct Analyzed by Inductively Coupled Plasma Spectroscopy

Components	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Mo	Na	Si
(ppm)	1860	63081	94658	139669	96854	4133	1471	53	941	454	32525	642

Table 2: Effect of Salt Industries Byproduct on Vegetative Growth and Yield in Lettuce

Treatment	Plant Height (cm)	Number of Leaf per Plant	Leaf Breadth (cm)	Leaf Length (cm)	Yield (g/plant)
T_1	28.09 a	19.00 a	9.22 a	23.01	42.93 b
T_2	24.06 a	20.67 a	12.97 a	20.93	51.33 a
T_3	19.11 b	14.33 b	7.86 b	19.27	36.56 c
P	0.020	0.011	0.001	0.303	0.011
	**	**	**	NS	**

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of one-way ANOVA. NSnonsignificant at $P \leq 0.05$. ** significant$P \leq 0.01$. DAT – Days after transfer.T_1: 0 $mL \cdot L^{-1}$ salt industries byproduct (SIB) + ¾ strength Rahman and Inden (2012), T_2: 0.5$mL \cdot L^{-1}$SIB + ¾ strength RahmanandInden (2012), T_3: 0.75$mL \cdot L^{-1}$SIB + ¾ strength Rahmanand Inden (2012).

Table 3: Effect of Salt Industries Byproduct on Plant Dry Weights in Lettuce

Treatment	Plant Dry Weight (g/Plant)	
	Leaf	Root
T_1	1.58 b	0.33 a
T_2	2.35 a	0.37 a
T_3	1.45 b	0.20 b
P	0.012	0.011
	**	**

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of one-way ANOVA. ** significant at $P \leq 0.01$. DAT – Days after transfer.T_1: 0 $mL \cdot L^{-1}$ salt industries byproduct (SIB) + ¾ strength Rahman and Inden (2012), T_2: 0.5 $mL \cdot L^{-1}$SIB + ¾ strength Rahman and Inden (2012), T_3: 0.75 $mL \cdot L^{-1}$SIB + ¾ strength Rahman and Inden (2012).

Table 4: Effects of Salt Industries Byproduct on Physiological Growth Traits of Lettuce

Treatment	LA (cm^2)	LMR ($g\ g^{-1}$)	LAR ($cm^2\ g^{-1}$)	RWR ($g\ g^{-1}$)	NAR ($g\ cm^{-2}\ d^{-1}$)	RGR ($g\ g^{-1}\ d^{-1}$)
T_1	145.01 b[z]	0.83 c	75.92 a	0.172 a	0.0000076 b	0.00054 b
T_2	179.45 a	0.88 a	65.97 b	0.136 b	0.0000115 a	0.00077 a
T_3	111.91 c	0.86 b	67.82 b	0.121 c	0.0000069 c	0.00047 c
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	**	**	**	**	**	**

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of one-way ANOVA. ** Significant at $P \leq 0.01$. LA = Leaf area; LMR = Leaf mass ratio; LAR = Leaf area ratio; RWR = Root weight ratio; NAR = Net assimilation rate; RGR = Relative growth rate.T_1: 0 $mL \cdot L^{-1}$ salt industries byproduct (SIB) + ¾ strength Rahman and Inden (2012), T_2: 0.5 $mL \cdot L^{-1}$SIB + ¾ strength Rahman and Inden (2012), T_3: 0.75 $mL \cdot L^{-1}$SIB + ¾ strength Rahman and Inden (2012).

Figure 1: Lettuce Culture in Hydroponic System at the Starting Time in the Laboratory of Sher-e-Bangla Agricultural University

Figure 2: Lettuce Culture in Hydroponic System at the End of the Experiment

PHYSICAL AND CHEMICAL PROPERTIES OF DIFFERENT SUBSTRATE MIXTURES AND THEIR EFFECTS ON GROWTH AND YIELD OF LETTUCE

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PHYSICAL AND CHEMICAL PROPERTIES OF DIFFERENT SUBSTRATE MIXTURES AND THEIR EFFECTS ON GROWTH AND YIELD OF LETTUCE

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Abstract: Carbonized rice husk, coco peat and sawdust are considered as good growing substrate components, but high water holding capacity causes poor air-water relationship, thus affecting oxygen diffusion to roots. Incorporation of coarser materials into these substrate components could improve aeration status. The present experiment aimed to assess the physicochemical properties of four growing substrate mixtures ((M_1 = 60% coconut coir + 30% khoa + 10% vermicompost, M_2= 60% Carbonised rice husk+ 30% khoa + 10% vermicompost, M_3= 60% sawdust + 30% khoa + 10% vermicompost, and M_4= 60% coconut coir + 30% rice husk + 10% vermicompost) and their effects on growth and yield of lettuce. Results revealed that pH, electrical conductivity (EC) were higher in M_2, whereas bulk density was higher in M_1 and the lowest in M_3. Improved properties of M_3 and M_4 positively reflected in growth, dry weight, and yield of lettuce. Therefore, it can be concluded that incorporation of coarser materials improved physicochemical properties of coco peat based treatment (M_4) followed by sawdust based treatment (M_3) that positively influenced the growth and yield of lettuce.

Key words**:** Hydroponics, Growing media, Physical properties, Chemical properties, Lettuce

Introduction

Use of suitable growing substrate is essential for production of high quality horticultural crops. It directly affects the development and later maintenance of the functional rooting system. A good growing medium provides a sufficient support to the plant, serves as reservoir for nutrients and water, allows oxygen diffusion to the roots and permits gaseous exchange between the roots and outside atmosphere (Abad *et al.*, 2002; Argo, 1998; Bunt, 1988; Richards and Beardsell, 1986). Many soilless materials are widely available in the tropics, viz., coconut coir, carbonized rice husk (CRH), sawdust, etc. These materials are mainly agricultural by-products and can be used as horticultural growing substrates. As a growing medium, coconut coir can be used to produce a number of crop species with acceptable pH, electrical

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conductivity (EC) and other chemical attributes in the tropics (Yahya *et al.*, 1997; Abad *et al.*, 2002). However, coconut coir has been recognized to have high water holding capacity which causes poor air-water relationship, leading to low aeration within the medium and it affects the oxygen diffusion to the roots.

CRH can be used as horticultural growing substrate although it has the problem of air-water relationship. When it is used as a component for growing substrate, it might behave like fine sand. However, it is lighter and sterile, and may contain some nutritional elements. CRH induced faster cell division and differentiation for root formation (Moe, 1988) and it was the best growing substrate for *Chrysanthemum* cutting (Budiartoa et al., 2006). Aside its use in nursery production, it may use as soilless growing media for sweet pepper production.

Sawdust is used as growing substrate and is available in almost all over the world and it could be renewable. Wood residues (i.e., sawdust and bark) have been used in containers for growing ornamentals (Klett*et al.*, 1972). But microorganisms involved in decomposition of raw wood residues are more efficient than higher plants in nitrogen absorption and assimilation (Alexander, 1961). Large amount of nitrogen must, therefore, be added to wood residues used as media to grow plants. This problem can be solved, however, by composting residues before using them for growing substrates (Still et al., 1974). However, physical and chemical properties of these substrate components are highly dependent on their processing technique and handling. It is desirable to improve physical and chemical properties of them before use as growing substrates.

Incorporation of coarser materials into the substrate components could improve the aeration and drainage status of the substrate mixtures (Bunt, 1988; Richards and Beardsell, 1986; Sambo *et al.*, 2008). Perlite (Islam, 2008; Sambo *et al.*, 2008), rice husk and brick broken can be the possible coarser materials that may improve the air-water relationship of the substrate components. Furthermore, a suitable combination of different growing substrate components positively influences the growth and yield of horticultural crop production like lettuce as a test crop. Thus, the objectives of this study were to assess the chemical and physical properties of different substrate mixtures, and their effects on growth and yield of lettuce.

Materials and Methods

Experimental site: The experiment was conducted in the greenhouse of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during January to March, 2016.

Experimental material: Lettuce cv. ‘Lolorossa’ was used for growing hydroponic system in the greenhouse. Seeds of lettuce were collected from University of Miyazaki, Japan and Siddique Bazar Seed Market, Dhaka.

Experimental environment: The seeds were sown in the media mixture of coco peat, brick broken and rice husk at the ratio of 6:2:2 (v/v) into the 20-mL plastic disposable pots. One week old seedlings were transferred in the different growing media mixtures in the pots. Three pots consisted as a treatment unit. The pH and EC of $\cong$ 6.0 and $\cong$ 2.8 – 3.0 $dS{\cdot}m^{-1}$, respectively were maintained in the nutrient solution.

Experimental Design: The experiment was conducted in a completely randomized design with four replications. Four substrate mixtures (M_1 = 60% coconut coir + 30% khoa + 10% vermicompost, M_2= 60% Carbonised rice husk+ 30% khoa + 10% vermicompost, M_3= 60% sawdust + 30% khoa + 10% vermicompost, and M_4= 60% coconut coir + 30% rice husk + 10% vermicompost). After the treatment started ½ strength Rahman and Inden (2012) was applied as a standard nutrient solution.

Data collection

Properties of growing substrate

The selected properties of growing substrate, namely initial pH and EC, bulk density, water retention, wettability, air-filled porosity and dry weight of substrate mixtures were measured. The measurement procedures of the properties were described below.

pH and EC: The pH and EC values for all media before planting were determined according to Yahya et al. (2009). For pH, 10 g of each media mixture was mixed with 50 mL distilled water, agitated for 30 minutes and left standing for 24 h. For EC, 40 g of each media mixture was mixed with 80 mL distilled water, shaken for 15 minutes and left for 1 h. A pH meter was used to measure pH and EC.

Bulk density (g·cm^{-3}): Bulk density was determined by using the core method (Teh and Jamal, 2006). In brief, the substrate mixtures in the core rings were saturated by allowing water to diffuse into the substrate for two days. The samples were oven-dried at 105°C for 24 h and recorded their weights. The bulk density (ρb) was calculated as the following formula,

$$\rho b = (W_b - W_r)/(\pi h_t d^2/4)$$

Where, W_b is the weight of oven dried substrate mixture and core ring, W_r is the weight of the core ring, h_t is the core ring height (cm) and d is the core ring diameter (cm).

Growth and yield parameters

Plant height and fresh weight were measured of lettuce.

Statistical analysis

Data were analyzed separately by one-way analysis of variance (ANOVA) for growing substrate mixtures properties and growth and yield parameters using SPSS (version 16.0, SPSS Inc., Chicago, IL). The differences among means were determined by Tukey's test at $P \leq 0.05$.

Results and Discussion

Properties of substrate mixtures

Initial pH and EC: The initial pH and EC are two important properties of growing substrate as these parameters directly influence the availability and indicate inherent nutrients status in the substrates. Variation in the growing substrate mixtures markedly affected the initial pH and EC (Table 1). The highest pH was recorded in M_2 followed by others. Meanwhile, the lowest pH was recorded in M_4. Blom (1983) stated that most of the plants grew best in slightly acidic pH ranges of 6.2- 6.8 in soil based substrates and 5.4-6.0 in soilless substrates. Furthermore, different plant species (and cultivars) have different pH range for optimal growth but overall optimum pH of the soilless substrates for adequate availability of essential plant nutrients is ≈6.0 (Yahya et al., 2009). The present findings revealed that the initial pH of the substrate mixtures of M_3 and M_4 were slightly higher than the optimum level that could be optimized by addition of acid based fertilizers.

Table 1. Initial pH and EC of substrate mixtures (before planting)

Substrate mixtures	pH	EC ($dS \cdot m^{-1}$)	Bulk density ($g \cdot cm^{-3}$)
M_1	6.68 b	0.11b	0.41a
M_2	7.38a	0.19a	0.24b
M_3	6.34c	0.08b	0.20c
M_4	6.13c	0.08b	0.22bc
P	<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% coconut coir + 30% khoa + 10% vermicompost, M_2= 60% Carbonised rice husk+ 30% khoa + 10% vermicompost, M_3= 60% sawdust + 30% khoa + 10% vermicompost, and M_4= 60% coconut coir + 30% rice husk + 10% vermicompost. *P* represents the level of significance of ANOVA.

On the other hand M_2 had the higher pH level for lettuce production. Very low pH can result in toxic concentration of ions such as aluminum, zinc and copper, while chemical bindings can occur at pH above 7.5 (Nappi and Barberis, 1993). All these phenomena lead to nutrients unavailability to the plants. However, the optimum pH of container substrates differs with plant species, but a pH of 5.0-6.5 can be tolerated by most of the plants (DeBoodt and Verndonck, 1972; Hans et al., 2005). The present results are consistent with these findings.

Regarding EC, M_2 possessed the highest initial EC. Meanwhile, M_3 had the lowest EC (Table 8). The EC values reflected the total inorganic ion concentration in the extracts of substrates. Yahya et al. (2009) reported the higher initial EC of burnt rice hull mixture which is consistent with the present findings. High EC above 3.5 $mS \cdot cm^{-1}$ in substrate causing poor plant growth (Eames, 1977; Hans et al., 2005; Lemaireet al., 1985). EC value below 2.0 $mS \cdot cm^{-1}$ is generally considered as optimum to support the plant growth in container production system (Milks et al., 1989). In this experiment, EC values for all the treatments did not exceed the optimum values for EC.

Bulk density: Bulk density differed significantly among the substrate mixtures (Table 9). The highest bulk density was found in M_1 and the lowest bulk density was found in M_3. The present result was consistent with the findings of Islam (2008) who found that the bulk density of loose rice husk was significantly lower than coconut coir. Bulk density differed most likely due to the variation in particle size of the materials (Richards and Beardsell, 1986). Bilderback et al. (2005) suggested that the acceptable range of bulk density for substrate is 0.19 to 0.70 $g \cdot cm^{-3}$. In this experiment, all the treatments had the bulk density within the acceptable range. Substrate mixture with low bulk density is required for frequently irrigated greenhouse to avoid oxygen deficiency.

Dry weight of substrate mixtures: Significant variation was found among different the treatments for dry weight of substrate mixtures (Table 9). The highest dry weight observed in M_1, while the lowest in M_4. Dry weight of substrate is an important criterion for easy mixing and transportation. It also affects construction materials for soilless culture. The grower can make hydroponic structure with low-cost materials, if the dry weights of substrate mixtures become low. The results of the present study indicated that carbonized rice husk (M_3) and sawdust (M_4) based substrates can facilitate the growers to construct hydroponic structure with low-cost materials. Furthermore, it can help easy mixing of the growing substrates.

Vegetative growth characteristics

Plant height: Plant height of lettuce was significantly affected by different growing substrates (Table 11). Plant height of lettuce tended to increase in M_4. The highest plant height was found in M_4, which was statistically similar to that of M_3. These might be due to improved properties of M_3 and M_4 that were discussed earlier. Lemaire (1995) reported that 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). On the other hand, carbonized rice husk is more sterile than the other substrates and it also contains more nutrients, but pH was higher compared to the other substrate. Therefore, lower plant height of lettuce was found in M_2.

Fresh weight: Marketable quality of lettuce is determined mainly by plant size, which depends on fresh weight. Fresh weight per plant was significantly varied among the different growing substrates (Table 12). The highest yield was found in M_4, which was statistically similar to that of M_3. In fact, this might be due to higher number of leaf and leaf breadth of lettuce grown in M_4aqnd M_3. In the present experiment, the physical and chemical properties of media mixtures were improved due to different mixtures.

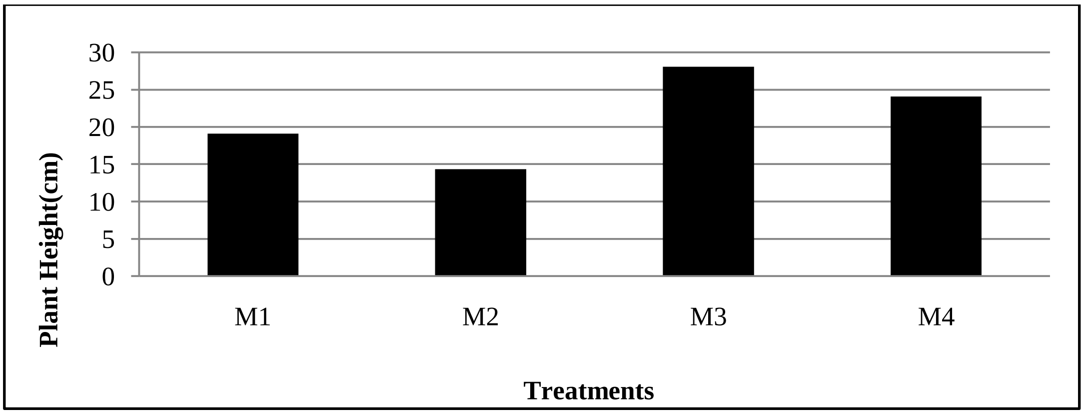

Fig.1. Effect of physical and chemical properties of different substrate mixture on plant height of lettuce. Vertical graph represents M_1 = 60% coconut coir + 30% khoa + 10% vermicompost, M_2= 60% Carbonised rice husk+ 30% khoa + 10% vermicompost, M_3= 60% sawdust + 30% khoa + 10% vermicompost, and M_4= 60% coconut coir + 30% rice husk + 10% vermicompost.

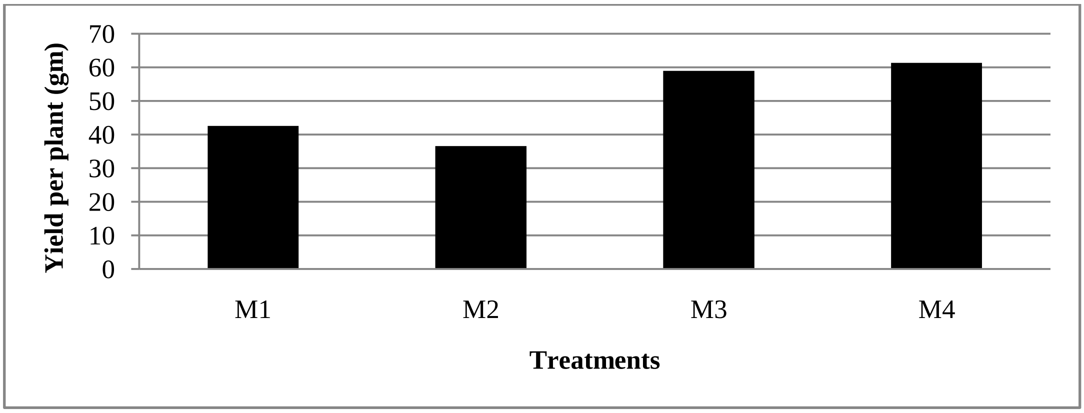

Fig.2. Effect of physical and chemical properties of different substrate mixture on yield per plant of lettuce. Vertical graph represents M_1 = 60% coconut coir + 30% khoa + 10% vermicompost, M_2= 60% Carbonised rice husk+ 30% khoa + 10% vermicompost, M_3= 60% sawdust + 30% khoa + 10% vermicompost, and M_4= 60% coconut coir + 30% rice husk + 10% vermicompost.

Conclusion

In conclusion, certain chemical and physical properties of M_4 and M_3 can be improved through incorporation of rice husk and khoa. The positive effects of M_4 and M_3 substrates were found on initial pH, EC, and low bulk density. Improved chemical and physical properties of M_4 and M_3 growing substrates showed better plant growth and yield of lettuce. On the contrary, improved physical and chemical properties were not found M_2 based substrate that negatively affected the growth and yield of lettuce. Therefore, it can be suggested that rice husk based substrate mixture (M_4) or sawdust (M_3) based growing substrates can be used for lettuce production in Bangladesh.

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