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Growth and Yield of Lettuce (*Lactuca Sativa* L.) Influenced As Nitrogen Fertilizer and Plant Spacing

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Abstract: *The experiment was conducted in the Research Field of Sher-e-Bangla Agricultural University, Dhaka from October 2014 to February 2015.The present study was conducted to determine the optimum level of nitrogen fertilizer and proper plant spacing for better growth and yield of lettuce. The experiment consisted of two factors. Factor A: Nitrogen (4 levels) N_0: 0 (Control); N_1: 50; N_2: 100 and N_3: 150 kg/ha respectively; and Factor B: Plant spacing (3 levels), S_1: 40 cm × 20 cm, S_2: 40 cm × 25 cm; S_3: 40 cm × 30 cm. The Experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In case of nitrogen the highest yield (29.99 t/ha) was recorded from N_3 and lowest (18.65 t/ha) from N_0. In case of spacing the highest yield (25.83 t/ha) was achieved from S_2 and lowest (23.0 t/ha) from S_1. For interaction effect, the highest yield (31.31 t/ha) was obtained from N_3S_2 and lowest (16.79 t/ha) from N_0S_1. The highest BCR value (3.88) was recorded from N_3S_2 and lowest (2.1) from N_0S_1. So, 150 kg/ha urea with spacing of 40 cm × 25 cm were best for growth and yield of lettuce.*

Key Words*: Nitrogen, Spacing, Growth, Yield, Lettuce*

I. Introduction

Lettuce (*Lactuca sativa* L.*)* an annual leafy herb belongs to the family Compositae is one of the most popular salad crops and occupies the largest production area among salad crops in the world. It is popular for its delicate, crispy texture and slightly bitter taste with milky juice as fresh condition. It is the most popular amongst the salad vegetable crops (Squire *et al*., 1987). Lettuce is rich in vitamin A and minerals like calcium and iron. It is usually used as salad with tomato, carrot, cucumber or other salad vegetable and often served alone or with dressing.

Lettuce is getting popularity day by day but its production package is not much known to the Bangladeshi farmers. This vegetable requires a high rate of nitrogen for growth and development. In Iran, farmers who applied excesses nitrogen fertilizer to increase crop yield disturbed the equilibrium balance of nutrient elements in the soil, caused pollution, decreased crop quality and thus a great part of the nation's resources became useless (Tehrani and Malakouti, 1997). Adequate N levels are also associated with "sizing," solid heads, and earliness of maturity in lettuce. Lettuce with N deficiency appears lighter green.

Plant spacing for lettuce cultivation is an important criterion for attaining maximum vegetative growth and an important aspect of crop production for maximizing the yield. Optimum plant spacing ensures judicious use of natural resources and makes the intercultural operations easier. It helps to increase the number of leaves, branches and healthy foliage. Densely planted crop obstruct the proper growth and development. On the other hand, wider spacing ensures the basic nutritional requirements but decrease the total number of plants as well as total yield. Yield may be increased for any crop up to 25% by using optimum spacing in leafy vegetable (Bansal, *et al*., 1995). Considering the above factors, the present study was undertaken to find out the suitable combination of nitrogen and plant spacing for ensuring the higher yield of lettuce.

II. Materials And Methods

The present experiment was carried out in the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^0 74^/$N latitude and $90^0 35^/$E longitude and at an elevation of 8.2 m from sea level (Anon., 1989). Seeds of lettuce cultivar, 'Grand Raphids' were used in the experiment. The experiment was laid out in Randomized Complete Block Design with three replications. The experiment consisted of two factors such as factor A: Nitrogen levels, N_0: 0 kg/ha (Control), N_1: 50 kg/ha, N_2: 100 kg/ha, N_3: 150 kg/ha and factor B: Plant spacing, S_1: 40 cm × 20 cm, S_2: 40 cm × 25 cm and S_3: 40 cm × 30 cm. There were 12 treatment combinations such as N_0S_1, N_0S_2, N_0S_3, N_1S_1, N_1S_2, N_1S_3, N_2S_1, N_2S_2, N_2S_3, N_3S_1, N_3S_2 and N_3S_3. There were 36 unit plots and the size of the each unit plot was 3.0 m × 1.6 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively.

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The data obtained for different parameters were statistically analyzed to find out the significance difference of nitrogen fertilization and plant spacing on yield and yield contributing characters of lettuce. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

III. Results And Discussion

3. 1. Plant height

Plant height of lettuce did not varied significantly between N_1, N_2 and N_3 level of nitrogen. But plant height varied significantly at 30, 40, 50 and 60 DAT (Table 1). At all the growth stages, the tallest plant (16.94, 21.85, 26.36 and 30.0 cm at 30, 40, 50 and 60 DAT respectively) was recorded from N_3 (150 kg N/ha) which was statistically similar (21.3 cm) to N_2 (100 kg N/ha) at 40 DAT. Again, the shortest plant (10.36, 13.7, 18.42 and 21.89 cm at 30, 40, 50 and 60 DAT respectively) was observed from N_0 (0 kg N/ha). It was revealed that with the higher doses of nitrogen level, increase plant height was observed, where no nitrogen application showed lowest plant height at all growth stages. Nitrogen fertilizer ensured favorable condition for the elongation of lettuce plant with optimum vegetative growth and the ultimate results was the tallest plant. Similar results were observed by Tittonell*et al*. (2003), Rincon *et al*. (1998) and Boroujerdnia and Ansari (2007).

Statistically significant variation on plant height of lettuce was shown due to different plant spacing at 30, 40, 50 and 60 DAT (Table 1). At different days after transplanting (DAT) the tallest plant (16.73, 22.2, 26.55 and 30.46 cm at 30, 40, 50 and 60 DAT respectively) was recorded from S_1 (40 cm × 20 cm). On the other hand, the shortest plant (13.3, 16.71, 21.0 and 24.21 cm at 30, 40, 50 and 60 DAT respectively) was found from S_3 (40 cm × 30 cm). Results under the present experiment showed that closer spacing showed higher plant height where higher plant spacing showed lower plant height because of closer spacing plant compete for light which helps to elongate plant than the wider spacing. Moniruzzaman (2006) reported similar findings from the closest spacing.

Significant variation was observed due to interaction effect of nitrogen and plant spacing in terms of plant height of lettuce at 30, 40, 50 and 60 DAT (Table 1). The tallest plant (20.0, 26.21, 31.89 and 35.01cm at 30, 40, 50 and 60 DAT, respectively) was recorded from N_3S_1. The combination of N_2S_1 also showed higher plant height but significantly different from N_3S_1.The shortest plant (9.71, 11.89, 17.54 and 20.11 cm at 30, 40 and 50 DAT, respectively) was found from N_0S_3. N_0S_2 which also showed lower plant height but significantly different from N_0S_3.

Table 1

3.2. Number of leaves/plant

Significant variation was recorded for number of leaves/plant of lettuce with application of different levels of nitrogen at 30, 40, 50 and 60 DAT (Table 2). At 30, 40, 50 and 60 DAT the maximum number of leaves/plant was 17.45, 24.85, 29.25 and 27.2 respectively which was obtained from N_3 (150 kg N/ha) and the minimum number of leaves/plant (12.65, 17.23, 22.7 and 21.45 at 30, 40, 50 and 60 DAT respectively) was found from N_0 (0 kg N/ha). It was revealed that the higher doses of nitrogen level showed higher number of leaves/plant where no nitrogen application showed the lowest at all growth stages. Maximum number of leaves/plant was recorded for highest level of nitrogen because nitrogenous fertilizer ensures favorable condition for the growth of lettuce. Similar findings were observed by Tittonell*et al*. (2003), Rincon *et al*. (1998) and Boroujerdnia and Ansari (2007).

No significant variation was found for number of leaves per plant between S_2 and S_3. But Due to different plant spacing, statistically significant variation was recorded for number of leaves per plant of lettuce at 30, 40, 50 and 60 DAT (Table 2). At different days after transplanting (DAT) the maximum number of leaves per plant (16.37, 23.14, 27.39 and 25.6 at 30, 40, 50 and 60 DAT respectively) was obtained from S_2 (40 cm × 25 cm) which was closely followed by S_3 (40 cm × 30 cm). At the same condition, the minimum number of leaves/plant (14.0, 19.68, 24.31 and 22.68 at 30, 40, 50 and 60 DAT respectively) was recorded from S_1 (40 cm × 20 cm). It was revealed that with the increases of spacing, number of leaves per plant also increased. Enough space for vertical and horizontal expansion in the optimum spacing that leads for production of maximum number of leaves per plant than the closer spacing. Steingrobe and Schenk (1994) also reported similar results earlier. Interaction effect of nitrogen and plant spacing showed significant difference among the treatments in terms of number of leaves per plant of lettuce at 30, 40, 50 and 60 DAT (Table 2). The maximum number of leaves/plant (19.16, 27.1, 31.77 and 29.71 at 30, 40, 50 and 60 DAT, respectively) was found from N_3S_2. The treatment combination of N_3S_3 also showed higher number of leaves/plant but significantly different from N_3S_2. Again, the minimum number of leaves/plant (11.54, 15.44, 21.34 and 20.51 at 30, 40, 50 and 60 DAT respectively) was attained from P_0S_1. It was revealed that optimum level of nitrogen and plant spacing ensured maximum number of leaves/plant.

Table 2

3.3. Leaf length

Application of different levels of nitrogen showed statistically significant variation for leaf length of lettuce at different days after transplanting (Table 3). At 30, 40, 50 and 60 DAT the highest leaf length was 13.0, 18.0, 22.41 and 25.28 cm respectively which was achieved from N_3 (150 kg N/ha). Again, the lowest leaf length (9.43, 10.63, 16.76 and 17.73 cm at 30, 40, 50 and 60 DAT respectively) was found from N_0 (0 kg N/ha). Results showed that higher doses of nitrogen cause higher leaf length. Optimum vegetative growth was occurred due to higher amount of nitrogen fertilizer that leads for the growth of lettuce and the ultimate results was the longest leaf. The results obtained earlier by Boroujerdnia and Ansari (2007) was similar with the present study.

Leaf length of lettuce was not significantly varied between S_2 and S_3. But leaf length was significantly influenced due to different plant spacing at 30, 40, 50 and 60 DAT (Table 3). The highest leaf length (12.44, 16.44, 21.13 and 23.67 cm at 30, 40, 50 and 60 DAT respectively) was observed from S_3 (40 cm × 30 cm) which was statistically identical with S_2 (40 cm × 25 cm) and the lowest leaf length (10.51, 12.88, 18.64 and 20.66 cm) was recorded from S_1 (40 cm × 20 cm). It was revealed that with the increases of spacing leaf length showed increasing trend. In case of closer spacing plant compete for light and with the time being leaf length decreases. Sodkowski and Rekowska (2003) reported longest leaf from closer spacing.

Statistically significant variation was recorded due to interaction effect of nitrogen and plant spacing in terms of leaf length of lettuce at 30, 40, 50 and 60 DAT (Table 3). The highest leaf length (13.89, 19.89, 23.79 and 27.00 cm at 30, 40, 50 and 60 DAT respectively) was found from N_3S_2. The similar result was also observed with N_3S_3 at 40 and 60 DAT. The lowest leaf length (8.94, 9.0, 15.19 and 16.0 cm at 30, 40, 50 and 60 DAT respectively) was obtained from N_0S_1. The treatment combination of N_0S_2 also showed lower leaf length but significantly different from N_3S_2 at 40, 50 and 60 DAT. Data revealed that optimum level of nitrogen and plant spacing ensured the highest leaf length with maximum vegetative growth.

Table 3

3.4. Leaf breadth

Application of different levels of nitrogen showed statistically significant variation for leaf breadth of lettuce at different days after transplanting (Table 4). At 30, 40, 50 and 60 DAT, the highest leaf breadth was 11.33, 15.58, 23.26 and 26.57 cm, respectively which was achieved from N_3 (150 kg N/ha). Again, the lowest leaf breadth (6.7, 9.63, 12.72 and 15.73 cm at 30, 40, 50 and 60 DAT respectively) was found from N_0 (0 kg N/ha). Results showed that higher doses of nitrogen cause higher leaf breadth. Optimum vegetative growth was occurred due to higher amount of nitrogen fertilizer that leads for the growth of lettuce and the ultimate results was the widest leaf. The results obtained earlier by Boroujerdnia and Ansari (2007) was similar with the present study.

Leaf breadth of lettuce was not significantly varied between S_2 and S_3. But leaf breadth was significantly influenced due to different plant spacing at 30, 40, 50 and 60 DAT (Table 4). The highest leaf breadth (10.45, 14.62, 21.18 and 24.69 cm at 30, 40, 50 and 60 DAT respectively) was observed from S_3 (40 cm × 30 cm) and the lowest leaf breadth (8.0, 11.54, 16.27 and 19.2 cm) was recorded from S_1 (40 cm × 20 cm). It was revealed that with the increases of spacing leaf breadth showed increasing trend. In case of closer spacing plant compete for light and with the time being leaf breadth decreases.

Statistically significant variation was recorded due to interaction effect of nitrogen and plant spacing in terms of leaf breadth of lettuce at different growth stages (Table 4). The highest leaf breadth (12.4, 16.99, 25.0 and 28.61 cm at 30, 40, 50 and 60 DAT respectively) was found from N_3S_3 which was statistically identical with N_3S_3 at 30, 40 and 60 DAT. The lowest leaf breadth (6.1, 8.0, 11.49 and 14.25 cm at 30, 40, 50 and 60 DAT respectively) was obtained from N_0S_1. The combination of N_0S_2 and N_0S_3 also showed lower leaf breadth but significantly different from N_3S_3 at 40, 50 and 60 DAT. Data revealed that optimum level of nitrogen and plant spacing ensured the highest leaf breadth with maximum vegetative growth.

Table 4

3.5. Fresh weight/plant

Lettuce fresh weight/plant showed statistically significant variation due to the application of different levels of nitrogen at different days after transplanting (Table 5). At 30, 40, 50 and 60 DAT the maximum fresh weight/plant (87.23, 102.3, 115.3 and 126.0 g respectively) was obtained from N_3 (150 kg N/ha) which was significantly different from all other treatments. On the other hand, the minimum fresh weight/plant (45.0, 56.12, 67.73 and 75.79 g at 30, 40, 50 and 60 DAT respectively) was found from N_0 (0 kg N/ha). It was revealed that with the increase of nitrogen application, fresh weight/plant increase due to optimum vegetative growth. Nitrogen fertilizer ensures favorable condition for the growth of lettuce with optimum vegetative growth and the ultimate results was the highest fresh weight/plant. The results obtained earlier by Tittonell*et al*.

(2003), Rincon *et al*. (1998) and Boroujerdnia and Ansari (2007) were similar with the present study. Fresh weight/plant of lettuce showed statistically significant variation due to different plant spacing at different growth stages (Table 5). At 30, 40, 50 and 60 DAT, the maximum fresh weight of plant (81.55, 94.58, 109.0 and 117.0 g at 30, 40, 50 and 60 DAT, respectively) was observed from S_3 (40 cm × 30 cm) while the minimum fresh weight/plant was 55.0, 65.4, 75.36 and 83.0 g respectively) was found from S_1 (40 cm × 20 cm). It was revealed that with the increases of spacing fresh weight of plant showed increasing trend. In case of wider spacing plant receive enough light and nutrients which leads to attain maximum fresh weight of plant. Similar result was also observed by Sharma *et al.* (2001). Interaction effect of different levels of nitrogen application and plant spacing showed statistically significant variation for fresh weight of lettuce plant at different growth stages (Table 5). The maximum fresh weight/plant (104.1, 120.1, 136.2 and 144.9 g at 30, 40, 50 and 60 DAT respectively) was found from N_3S_3 where the minimum fresh weight/plant (36.65, 44.69, 54.44 and 62.59 g) was with N_0S_1. It was revealed that optimum level of nitrogen and plant spacing ensured maximum vegetative growth that ensured highest fresh weight/ plant.

Table 5

3.6. Dry weight/plant

Lettuce dry weight/plant showed statistically significant variation due to the application of different levels of nitrogen at different growth stages (Table 6). At 30, 40, 50 and 60 DAT, the maximum dry weight/plant (12.46, 14.68, 16.56 and 18.0 g, respectively) was obtained from N_3 (150 kg N/ha) which was significantly different from all other treatments. On the other hand, the minimum dry weight/plant (6.8, 8.23, 9.83 and 10.89 g at 30, 40, 50 and 60 DAT respectively) was found from N_0 (0 kg N/ha). It was revealed that with the increase of nitrogen application, dry weight/plant increase due to more availability of nutrients among the plants during vegetative growth. Similar results were also obtained by Tittonell*et al*. (2003) and MahmoudiKliber (2005). Dry weight/plant of lettuce showed statistically significant variation due to different plant spacing at different growth stages (Table 6). At 30, 40, 50 and 60 DAT, the maximum dry weight/plant (11.83, 13.72, 15.67 and 16.81 g at 30, 40, 50 and 60 DAT respectively) was observed from S_3 (40 cm × 30 cm) while the minimum dry weight/plant was 8.0, 9.36, 10.84 and 10.89 g respectively was found from S_1 (40 cm × 20 cm). It was revealed that with the increases of spacing dry weight of plant showed increasing trend because of less competition for nutrients among the plants during growth stages. Similar result was also tested by Sharma *et al.* (2001). Interaction effect of different levels of nitrogen application and plant spacing showed statistically significant variation for dry weight of lettuce plant at different growth stages (Table 6). The maximum dry weight/plant (14.94, 17.29, 19.56 and 20.8 g at 30, 40, 50 and 60 DAT, respectively) was found from N_3S_3 where the minimum dry weight/plant (5.84, 6.85, 7.76 and 8.99 g) was with N_0S_1. It was revealed that optimum level of nitrogen and plant spacing ensured maximum vegetative growth that ensured highest dry weight/plant.

Table 6

3.7. Yield/ha

Different levels of nitrogen application influenced yield/ha significantly at different growth stages of lettuce (Table 7). At 30, 40, 50 and 60 DAT, the highest yield/ha was 6.0, 7.15, 8.0 and 8.76 t, respectively from N_3 (150 kg N/ha) which was statistically similar (6.58 and 7.0 t at 40 and 50 DAT respectively) with N_2 (100 kg N/ha). On the other hand, the lowest yield/ha (3.0, 4.43, 5.31 and 5.9 t at 30, 40, 50 and 60 DAT respectively) was recorded from N_0 (0 kg N/ha). It was revealed that with increase of nitrogen maximizes lettuce yield because of increased nitrogen helps plant for higher vegetative growth. The results obtained earlier by Rincon *et al*. (1998), Tittonell*et al*. (2003), Boroujerdnia and Ansari (2007) and MahmoudiKliber (2005) was similar with the present study. Yield/ha of lettuce was statistically significant in terms of different plant spacing at different growth stages (Table 7). At 30, 40, 50 and 60 DAT, the maximum yield/ha (4.98, 6.17, 7.03 and 7.66 t respectively) was obtained from S_2 (40 cm × 25 cm).On the other hand, the lowest yield/ha (4.19, 5.76, 6.35 and 6.96 t at 30, 40, 50 and 60 DAT respectively) was recorded from S_1 (40 cm × 25 cm). It was revealed that with the increases of spacing individual weight per plant increase. So, in spite of less population, total yield/ha may higher due to higher individual plant weight and optimum spacing ensure the highest yield with maximum vegetative growth. Similar result was also tested by Sharma *et al.* (2001). Significant variation was examined due to interaction effect of different levels of nitrogen and plant spacing in terms of yield/ha at different growth stages of lettuce crop (Table 7). Results showed that the highest yield/ha were 6.44, 7.41, 8.31 and 9.15 t at 30, 40, 50 and 60 DAT respectively from N_3S_2. The lowest yield/ha (2.84, 3.89, 4.75 and 5.34 t at 30, 40, 50 and 60 DAT respectively) was recorded from N_0S_1 which was statistically similar with N_0S_2 at 30 DAT. It was revealed that optimum level of nitrogen and plant spacing ensured maximum vegetative growth and the allocation of optimum number of plants that leads to produce the highest yield/ha.

Table 7

3.8. Total yield

Different levels of nitrogen application influenced total yield of lettuce significantly (Figure 1). It was observed that the highest yield (29.99 t/ha) was obtained from N_3 (150 kg N/ha) where the lowest yield (18.65 t/ha) was recorded from N_0 (0 kg N/ha). It was remarked that higher yield was achieved with higher doses of nitrogen due helping plants for higher vegetative growth. The results obtained earlier by Rincon *et al*. (1998), Tittonell*et al*. (2003), Boroujerdnia and Ansari (2007) and MahmoudiKliber (2005) was similar with the present study.

Figure 1

Total yield of lettuce was significantly influenced by different plant spacing (Figure 2). Results indicated that the maximum yield (25.83 t/ha) was obtained from S_2 (40 cm × 25 cm).On the other hand, the lowest yield (23 t/ha) was recorded from S_1 (40 cm × 20 cm). It was said that higher spacing showed higher yield till to a certain level because of higher population is ensured with lower spacing and higher spacing provide more nutrients and less competition of nutrition for vegetative growth. Similar result was also tested by Sharma *et al.* (2001).

Figure 2

Significant variation was examined due to interaction effect of different levels of nitrogen and plant spacing in terms of total yield of lettuce crop (Table 8). Results showed that the highest yield (31.31 t/ha) was obtained from N_3S_2 where the lowest (16.79 t/ha) was from N_0S_1. It was stated that optimum level of nitrogen and plant spacing ensured maximum vegetative growth and ultimate result is to produce the highest yield. Similar result was also achieved by Tittonell*et al.* (2001).

3.9. Benefit cost ratio (BCR)

The combination of nitrogen fertilizer and plant spacing showed different benefit cost ratio in different treatment combinations (Table 8). The highest benefit cost ratio (BCR) (3.887) was performed from N_3S_2 and the second BCR (3.67) was estimated from N_3S_1. The lowest benefit cost ratio (2.10) was obtained from N_0S_1. From economic point of view, it is apparent from the above results that N_3S_2 was the more profitable than rest of the treatment combinations for lettuce crop. Under the present study, the ultimate goal was to achieve highest return with lettuce cultivation applying different treatment combinations and from this point of view the highest net return Benefit Cost Ratio (3.88) were achieved from N_3S_2 where the lowest Benefit Cost Ratio (2.1) were from N_0S_1. From economic point of view, it is apparent from the above results that N_3S_2 was the most profitable than rest of the treatment combinations for lettuce cultivation.

Table 8

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Table 1: Effect of nitrogen and plant spacing on plant height at different growth stages of lettuce crop

Treatment	Plant height (cm)			
	30 DAT	40 DAT	50 DAT	60 DAT
Main effect of nitrogen				
N_0	10.36 c	13.79 c	18.42 c	21.98 d
N_1	16.46 b	21.05 b	25.59 b	28.77 c
N_2	16.33 b	21.30 ab	25.23 b	29.07 b
N_3	16.94 a	21.85 a	26.36 a	30.00 a
Main effect of spacing				
S_1	16.73 a	22.20 a	26.55 a	30.46 a
S_2	15.05 b	19.58 b	24.15 b	27.70 b
S_3	13.30 c	16.71 c	21.00 c	24.21 c
Interaction effect of nitrogen and spacing				
N_0S_1	11.11 h	15.89 g	19.11 gh	23.11 hi
N_0S_2	10.26 i	13.59 h	18.61 hi	22.71 i
N_0S_3	9.71 i	11.89 i	17.54 i	20.11 j
N_1S_1	17.61 bc	22.91 bc	27.61 b	31.44 bc
N_1S_2	16.12 de	20.69 de	25.04 de	27.99 e
N_1S_3	15.66 e	19.55 e	24.11 e	26.89 ef
N_2S_1	18.10 b	23.80 b	27.59 b	32.24 b
N_2S_2	16.59 d	21.79 cd	25.96 cd	29.60 d
N_2S_3	14.31 f	18.31 f	22.16 f	25.39 fg
N_3S_1	20.09 a	26.21 a	31.89 a	35.05 a
N_3S_2	17.21 c	22.24 c	27.00 bc	30.51 cd
N_3S_3	13.51 g	17.10 fg	20.20 g	24.44 gh
CV(%)	7.46	8.93	6.44	7.81

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 2: Effect of nitrogen and plant spacing on number of leaves/plant at different growth stages of lettuce crop

Treatment	Number of leaves/plant			
	30 DAT	40 DAT	50 DAT	60 DAT
Main effect of nitrogen				
N_0	12.65 d	17.23 d	22.70 d	21.45 c
N_1	15.46 c	22.26 c	26.10 c	24.32 b
N_2	16.44 b	23.60 b	27.33 b	25.34 b
N_3	17.45 a	24.85 a	29.25 a	27.20 a
Main effect of spacing				
S_1	14.03 b	19.68 b	24.31 b	22.68 b
S_2	16.37 a	23.14 a	27.39 a	25.60 a
S_3	16.10 a	23.13 a	27.33 a	25.45 a
Interaction effect of nitrogen and spacing				
N_0S_1	11.54 g	15.44 i	21.34 j	20.51 h
N_0S_2	13.00 f	17.81 h	23.04 i	21.70 gh
N_0S_3	13.40 ef	18.44 h	23.70 hi	22.14 g
N_1S_1	14.54 de	19.94 g	24.66 gh	23.01 fg
N_1S_2	15.79 b-d	23.04 de	26.60 e	24.80 de
N_1S_3	16.04 bc	23.79 cd	27.06 de	25.15 de
N_2S_1	14.89 cd	21.24 f	25.15 fg	23.11 fg
N_2S_2	16.46 b	24.60 bc	28.14 cd	26.20 cd
N_2S_3	17.99 a	24.96 bc	28.70 bc	26.71 bc
N_3S_1	15.14 b-d	22.11 ef	26.11 ef	24.09 ef
N_3S_2	19.16 a	27.10 a	31.77 a	29.71 a
N_3S_3	18.04 a	25.34 b	29.87 b	27.80 b
CV(%)	5.48	7.66	8.14	7.24

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 3: Effect of nitrogen and plant spacing on leaf length at different growth stages of lettuce crop

Treatment	Leaf length (cm)			
	30 DAT	40 DAT	50 DAT	60 DAT
Main effect of nitrogen				
N_0	9.43 d	10.63 d	16.76 d	17.73 d
N_1	11.68 c	15.32 c	20.33 c	22.95 c
N_2	12.38 b	16.60 b	21.33 b	24.23 b
N_3	13.09 a	18.03 a	22.41 a	25.28 a
Main effect of spacing				
S_1	10.51 b	12.88 b	18.64 b	20.66 b
S_2	11.99 a	16.10 a	20.87 a	23.32 a
S_3	12.44 a	16.44 a	21.13 a	23.67 a
Interaction effect of nitrogen and spacing				
N_0S_1	8.94 g	9.09 i	15.19 j	16.09 i
N_0S_2	9.15 g	10.89 h	17.10 i	18.00 h
N_0S_3	10.20 f	11.90 gh	18.00 h	19.11 g
N_1S_1	10.64 f	13.15 fg	18.96 g	21.26 f
N_1S_2	12.00 de	16.10 cd	20.90 de	23.39 de
N_1S_3	12.40 cd	16.71 cd	21.14 de	24.21 cd
N_2S_1	10.80 f	14.00 ef	19.89 f	22.40 e
N_2S_2	12.90 bc	17.54 bc	21.70 cd	24.90 bc
N_2S_3	13.44 ab	18.26 b	22.42 bc	25.40 b
N_3S_1	11.66 e	15.29 de	20.51 ef	22.89 e
N_3S_2	13.89 a	19.89 a	23.79 a	27.00 a
N_3S_3	13.71 a	18.90 ab	22.94 b	25.96 ab
CV(%)	6.57	6.28	7.22	8.36

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 4: Effect of nitrogen and plant spacing on leaf breadth at different growth stages of lettuce crop

Treatment	Leaf breadth (cm)			
	30 DAT	40 DAT	50 DAT	60 DAT
Main effect of nitrogen				
N_0	6.70 d	9.63 d	12.72 d	15.73 d
N_1	9.78 c	14.04 c	19.66 c	23.18 c
N_2	10.33 b	14.28 b	21.66 b	25.01 b
N_3	11.33 a	15.58 a	23.26 a	26.57 a
Main effect of spacing				
S_1	8.09 c	11.54 c	16.27 c	19.20 c
S_2	10.07 b	13.99 b	20.53 b	23.99 b
S_3	10.45 a	14.62 a	21.18 a	24.69 a
Interaction effect of nitrogen and spacing				
N_0S_1	6.10 g	8.04 i	11.49 i	14.25 i
N_0S_2	6.69 fg	10.00 h	12.90 h	16.01 h
N_0S_3	7.31 f	10.86 g	13.79 h	16.94 h
N_1S_1	8.14 e	13.56 de	15.80 g	18.99 g
N_1S_2	10.39 c	13.80 d	21.00 de	24.66 d
N_1S_3	10.80 bc	14.75 c	22.19 cd	25.90 cd
N_2S_1	8.70 de	11.70 f	17.91 f	20.86 f
N_2S_2	11.01 bc	15.24 bc	23.34 bc	26.89 bc
N_2S_3	11.29 b	15.89 b	23.74 ab	27.30 ab
N_3S_1	9.40 d	12.84 e	19.89 e	22.70 e
N_3S_2	12.19 a	16.90 a	24.89 a	28.40 a
N_3S_3	12.40 a	16.99 a	25.01 a	28.61 a
CV(%)	8.33	7.49	6.87	9.24

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 5: Effect of nitrogen and plant spacing on fresh weight/plant at different growth stages of lettuce crop

Treatment	Fresh weight/plant			
	30 DAT	40 DAT	50 DAT	60 DAT
Main effect of nitrogen				
N_0	45.07 d	56.12 d	67.73 d	75.79 d
N_1	66.66 c	78.29 c	91.77 c	98.38 c
N_2	77.86 b	89.04 b	99.58 b	108.90 b
N_3	87.23 a	102.30 a	115.30 a	126.00 a
Main effect of spacing				
S_1	55.06 c	65.40 c	75.36 c	83.01 c
S_2	71.01 b	84.34 b	96.39 b	106.8 b
S_3	81.55 a	94.58 a	109.00 a	117.00 a
Interaction effect of nitrogen and spacing				
N_0S_1	36.65 j	44.69 h	54.44 h	62.59 h
N_0S_2	46.21 i	59.55 g	70.34 g	79.49 g
N_0S_3	52.36 h	64.11 f	78.39 ef	85.29 f
N_1S_1	54.24 h	62.54 fg	74.66 f	80.11 g
N_1S_2	68.46 f	80.89 d	94.43 d	103.50 e
N_1S_3	77.29 e	91.45 c	106.2 c	111.50 d
N_2S_1	60.89 g	71.99 e	80.89 e	88.11 f
N_2S_2	80.24 d	92.49 c	102.6 c	112.20 d
N_2S_3	92.44 b	102.60 b	115.3 b	126.40 c
N_3S_1	68.45 f	82.36 d	91.46 d	101.20 e
N_3S_2	89.14 c	104.40 b	118.2 b	132.00 b
N_3S_3	104.10 a	120.10 a	136.2 a	144.90 a
CV(%)	8.88	7.98	9.42	7.66

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 6: Effect of nitrogen and plant spacing on dry weight/plant at different growth stages of lettuce crop

Treatment	Dry weight/plant			
	30 DAT	40 DAT	50 DAT	60 DAT
Main effect of nitrogen				
N_0	6.80 d	8.23 d	9.83 d	10.89 d
N_1	9.74 c	11.08 c	13.21 c	14.16 c
N_2	11.32 b	12.80 b	14.32 b	15.66 b
N_3	12.46 a	14.68 a	16.56 a	18.05 a
Main effect of spacing				
S_1	8.09 c	9.36 c	10.84 c	11.89 c
S_2	10.31 b	12.02 b	13.93 b	15.37 b
S_3	11.83 a	13.72 a	15.67 a	16.81 a
Interaction effect of nitrogen and spacing				
N_0S_1	5.84 g	6.85 g	7.76 g	8.99 f
N_0S_2	6.86 fg	8.19 fg	10.46 f	11.39 e
N_0S_3	7.69 ef	9.66 ef	11.29 f	12.29 e
N_1S_1	7.95 ef	8.40 fg	10.79 f	11.65 e
N_1S_2	9.89 d	11.67 cd	13.56 d	14.88 cd
N_1S_3	11.39 c	13.19 bc	15.29 bc	15.94 cd
N_2S_1	8.88 de	10.36 de	11.64 ef	12.46 e
N_2S_2	11.75 c	13.29 bc	14.78 cd	16.31 c
N_2S_3	13.31 b	14.74 b	16.54 b	18.20 b
N_3S_1	9.69 d	11.84 cd	13.19 de	14.45 d
N_3S_2	12.75 bc	14.93 b	16.94 b	18.90 b
N_3S_3	14.94 a	17.29 a	19.56 a	20.80 a
CV(%)	4.68	7.84	5.23	6.11

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 7: Effect of nitrogen and plant spacing on yield (t/ha) at different growth stages of lettuce crop

Treatment	Yield (t/ha)			
	30 DAT	40 DAT	50 DAT	60 DAT
Main effect of nitrogen				
N_0	3.01 c	4.43 c	5.31 c	5.90 c
N_1	4.11 b	5.62 b	6.39 b	6.98 b
N_2	5.00 b	6.58 ab	7.08 ab	7.63 b
N_3	6.08 a	7.15 a	8.00 a	8.76 a
Main effect of spacing				
S_1	4.19 b	5.76 b	6.35 c	6.96 c
S_2	4.98 a	6.17 a	7.03 a	7.66 a
S_3	4.49 b	5.91 ab	6.71 b	7.33 b
Interaction effect of nitrogen and spacing				
N_0S_1	2.84 i	3.89 k	4.75 h	5.34 h
N_0S_2	3.01 hi	4.50 j	5.46 g	6.01 g
N_0S_3	3.19 h	4.91 i	5.74 fg	6.34 fg
N_1S_1	3.50 g	5.21 h	5.96 ef	6.54 ef
N_1S_2	4.96 d	6.16 f	7.00 cd	7.59 cd
N_1S_3	3.86 f	5.50 g	6.21 e	6.81 e
N_2S_1	4.31 e	6.79 cd	6.75 d	7.29 d
N_2S_2	5.49 c	6.59 de	7.34 c	7.89 c
N_2S_3	5.21 d	6.35 ef	7.16 c	7.71 c
N_3S_1	6.10 b	7.14 b	7.96 b	8.66 b
N_3S_2	6.44 a	7.41 a	8.31 a	9.15 a
N_3S_3	5.71 c	6.89 bc	7.75 b	8.46 b
CV(%)	4.53	6.57	7.28	8.44

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

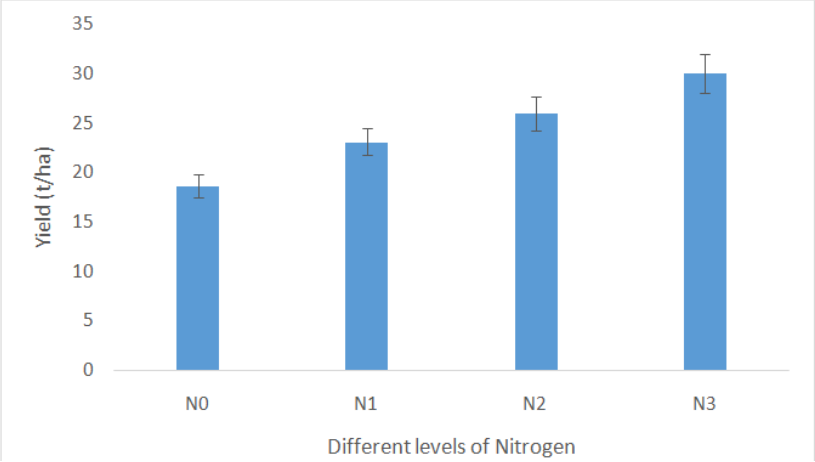

Figure 1: Effect of nitrogen on total yield of lettuce

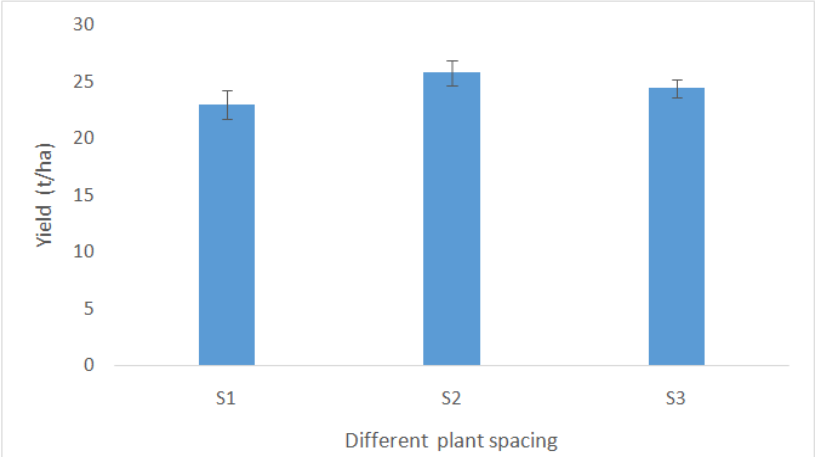

Figure 2: Effect of different plant spacing on total yield of lettuce

Table 8: The combined effect of nitrogen and plant spacing on total yield and BCR of lettuce crop

Treatments	Total Yield (t/ha)	Benefit cost ratio (BCR)
N_0S_1	16.79 j	2.100
N_0S_2	19.00 i	2.393
N_0S_3	20.16 hi	2.550
N_1S_1	21.21 gh	2.643
N_1S_2	25.71 de	3.213
N_1S_3	22.39 fg	2.813
N_2S_1	24.14 ef	2.993
N_2S_2	27.29 cd	3.393
N_2S_3	26.44 d	3.307
N_3S_1	29.86 ab	3.663
N_3S_2	31.31 a	3.887
N_3S_3	28.80 bc	3.580
CV(%)	7.78	5.66

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability