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Determining the combined effect of nitrogen and spacing on growth parameters in lettuce (*Lactuca sativa* L.)

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Abstract
This study aims to evaluate the efficacy of nitrogen and spacing on lettuce performance. The experiment was laid out as a randomized block design (RBD) with four N levels N_0 (0 kg/ha), N_1 (60 kg/ha), N_2 (120 kg/ha) and N_3 (180kg/ha) and three different spacing S_1 (45 cm × 20 cm), S_2 (45 cm × 25 cm) and S_3 (45cm ×30 cm). In case of nitrogen the highest plant height (11.97, 23.14 and 29.12 cm), number of leaves/plant (12.98, 21.11 and 24.42), leaf length (13.04, 18.97 and 25.97 cm) and leaf width (12.78, 16.15 and 28.68 cm) at 30, 45 and 60 DAT was recorded from N_3 and likewise, the effect of spacing gave maximum plant height (11.33, 21.53 and 27.38 cm), number of leaves/plant (14.42, 23.78 and 27.17), leaf length (12.44, 17.60 and 25.75 cm) and leaf width (11.97, 15.05 and 25.10 cm) at 30, 45 and 60 DAT respectively was observed from S_3. For interaction effect, plant height (12.89, 23.58 and 29.37cm), number of leaves/Plant (16, 27.70 and 32.64), leaf length (14.08, 19.80 and 29 cm) and leaf width (13.80, 17.28 and 30.36 cm) at 30, 45 and 60 DAT respectively was found from N_3S_3. This study showed that for optimal growth of lettuce ought to be grown using nitrogen level 180 kg N ha^{-1} and spacing 45 x 30 cm.

Keywords: Nitrogen level, spacing adjustment, growth parameters

Introduction
Lettuce (*Lactuca sativa* L.), an annual leafy herb plant belongs to the Compositae family having chromosome number 2n=18. Lettuce is rich source of vitamin A (276 IU/100g), Vitamin C (3.7mg/100g and minerals like calcium (35mg/100g) and iron (1.1g/100g). It is popular for its mild, crispy texture and slightly bitter taste with milky juice as fresh condition. It is usually used as salad with tomato, cucumber or other salad vegetables and often served alone or with dressing. Lettuce is unique among major vegetables in its nearly exclusive use as a fresh, raw product. Its nutritive value is not spoiled. Moreover, it is also known as analgesic, sedative, diuretic and expectorant (Kallo, 1986**)** [7]**.** "Mixed lettuce" production includes green leaf, red leaf, butter and romaine types. These crops are often planted alongside endive, escarole, oriental vegetables, herbs and other leafy. Smaller operations focus on high quality produce and cater to farmer's markets or to hotels, restaurants and other high-end food service companies, but the volume of high-quality specialty products is also increasing in main-stream retail stores.

Nitrogen (N) is an important plant nutrient that can be absorbed primarily in the form of nitrate. It constitutes about 1.5–6% of the dry weight of many crops, Jone *et al.* (1991) [6]. Among the various factors, the level of nutrient application and plant spacing is very important factor for lettuce production, Verker *et al.* (1973) [17]. Surplus nitrates late in the growing season tend to cause loose heads. Excess nitrogen causes increased susceptibility of vegetable crops to fungus disease and deterioration of postharvest quality. However, inadequate fertilizer application retards development, reduces quality, and encourages bolting in lettuce (Collingwood, 1988) [3]. Plant spacing for lettuce cultivation is an important measure 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 vigorous foliage. Densely planted crop hampers 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) [1].

Materials and Methods

A field experiment was carried out during October 2018 to February 2019, to assess the combined effect of nitrogen and spacing on growth parameters for yield improvement in lettuce at Horticulture Research Farm-I of the Department of Horticulture, Babasaheb Bhimrao Ambedkar University (A Central University) Vidya-Vihar Raebareli Road, Lucknow (U.P.), India which is located at 26 55' North Latitude and 80 59' East longitude and 124 m altitude above the mean sea level. The soil of the experimental field was sandy loam and slightly alkaline in nature with the soil pH 8.2, low organic carbon (0.12%), available N (110.50 kg/ha) available P (40.50 kg/ha), EC (0.26 ds/m), available K (190.40 kg/ha). Great Lakes variety seed was used for sowing during the research trial. The experiment was laid out in Factorial Randomized Block Design comprising of 12 treatments which are replicated thrice. Treatment combination consisted of two factors, one with four levels of nitrogen i.e., N_0: 0 kg/ha (Control), N_1: 60 kg/ha, N_2: 120 kg/ha and N_3: 180 kg/ha and other with three different spacing i.e., S_1: 45 cm x 20 cm, S_2: 45 cm x 25 cm and S_3: 45 cm x 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 plots and the size of the plot was 1.80 m x 1.20 m. The data obtained for different parameters were statistically analyzed to find out the significance difference of nitrogen fertilization and plant spacing on growth characters of lettuce. The data obtained was analyzed using OPSTAT software.

Results and Discussions

Plant height

Plant height of lettuce was observed significantly found between N_1, N_2 and N_3 level of nitrogen at 30, 45 and 60 DAT. At all the growth stages, the tallest plant (11.97, 23.14 and 29.12 cm) at 30, 45 and 60 DAT respectively) was recorded from N_3 (180 kg N/ha). However, the shortest plant (9.93, 15.65 and 22.91 cm) at 30, 45 and 60 DAT respectively (Figure 1, 2, 3 and 4) was observed from N_0 (Control). Nitrogen fertilizer ensured favorable condition for the elongation of lettuce plant with optimum vegetative growth and the ultimate results was the tallest plant. 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. Similar results were observed by Rincon *et al*. (1998) [10], Tittonell *et al.* (2003) [16] and Boroujerdnia and Ansari (2007) [2].

Statistically significant variation on plant height of lettuce was shown due to different spacing at 30, 45 and 60 DAT (Table 2). At different days after transplanting (DAT) the tallest plant (11.33, 21.53 and 27.38 cm) at 30, 45 and 60 DAT respectively was recorded from S_3 (45 cm × 30 cm). On the other hand, the shortest plant (9.74, 81.71 and 25.08 cm) at 30, 45 and 60 DAT respectively was found from S_3 (45 cm × 20 cm). Results under the present experiment showed that closer spacing showed lower plant height where higher plant spacing showed higher plant height because of closer spacing plant compete for light which helps to elongate plant than the wider spacing. Moniruzzaman (2006) [9] 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, 45 and 60 DAT (Table 2). The tallest plant (12.89, 23.58 and 29.37cm) at 30, 45 and 60 DAT, respectively was recorded from N_3S_3. The shortest plant (7.94, 12.20 and 18.41 cm) at 30, 45 and 60 DAT, respectively was found from N_0S_1.

Number of leaves/Plant

Significant variation was recorded for number of leaves per plant of lettuce with application of different levels of nitrogen at 30, 45 and 60 DAT (14.70, 24.56 and 27.39 respectively) at 30, 45 and 60 DAT which was obtained from N_3 (180 kg N/ha) and the minimum number of leaves/plant (12.98, 21.11 and 24.42) at 30, 45 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 Rincon *et al.* (1998) [10] and Tittonell *et al.* (2003) [16].

Analysis of the result showed that different spacing effects significantly affected the number of leaves per plant of lettuce. Statistically significant variation was recorded for number of leaves per plant of lettuce (Table 2). At different days after transplanting the maximum number of leaves per plant (14.42, 23.78 and 27.17) at 30, 45 and 60 DAT respectively was obtained from S_3 (45 cm × 30 cm). At the same condition, the minimum number of leaves/plant (12.94, 21.78 and 24.63) at 30, 45 and 60 DAT respectively was recorded from S_1 (45 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) [13] also reported similar results earlier.

Interaction effect of nitrogen and spacing showed significant difference among the treatments in terms of number of leaves per plant of lettuce at 30, 45 and 60 DAT (Table 2). The maximum number of leaves/plant (16, 27.70 and 32.64) at 30, 45 and 60 DAT, respectively was found from N_3S_3. Again, the minimum number of leaves/plant (11.25, 18.34 and 22.36 at 30, 45) and 60 DAT respectively was attained from N_0S_1. It was revealed that optimum level of nitrogen and plant spacing ensured maximum number of leaves/Plant.

Leaf length

Application of different levels of nitrogen showed statistically significant variation for leaf length of lettuce at different days after transplanting. At 30, 45 and 60 DAT the highest leaf length was 13.04, 18.97 and 25.97 cm respectively which was achieved from N_3 (180 kg N/ha). Again, the lowest leaf length (11.19, 14.56 and 23.28 cm) at 30, 45 and 60 DAT respectively was found from N_0 (Control). 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) [2] and Hasan *et al.* (2017) [5] was similar with the present study.

Similarly, the main effect of spacing significantly affected the highest leaf length (12.44, 17.60 and 25.75 cm) at 30, 45 and 60 DAT respectively was observed from S_3 (45 cm × 30 cm) and the lowest leaf length (11.09, 13.05 and 23.75 cm) was recorded from S_1 (45 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) [12] observed longest leaf from optimum spacing.

Statistically significant variation was recorded due to interaction effect of nitrogen and spacing in terms of leaf length of lettuce at 30, 45 and 60 DAT. The highest leaf length (14.08, 19.80 and 29 cm) at 30, 45 and 60 DAT respectively was found from N_3S_3. The lowest leaf length (9.64, 10.05 and 19.38 cm at 30, 45 and 60 DAT respectively) was obtained from N_0S_1. The treatment combination of N_0S_1 also showed lower leaf length. Data revealed that optimum level of nitrogen and spacing ensured the highest leaf length with maximum vegetative growth. Hasan *et al.* (2017) [5] reported that the optimum level of nitrogen and plant spacing ensured the highest leaf length with maximum vegetative growth.

Leaf Width

Application of different levels of nitrogen showed statistically significant variation for leaf width of lettuce at different days after transplanting. At 30, 45 and 60 DAT, the highest leaf width was 12.78, 16.15 and 28.68 cm, respectively which was achieved from N_3 (180 kg N/ha). Again, the lowest leaf width (10.48, 13.09 and 21.35 cm) at 30, 45 and 60 DAT respectively was found from N_0 (Control). Results showed that higher doses of nitrogen cause higher leaf width. 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) [2] was similar with the present study.

Leaf width of lettuce was significantly influenced due to different spacing at 30, 45 and 60 DAT. The highest leaf width (11.97, 15.05 and 25.10 cm) at 30, 45 and 60 DAT respectively was observed from S_3 (45 cm × 30 cm) and the lowest leaf width (10.65, 13.65 and 23.94 cm) was recorded from S_1 (45 cm × 20 cm). It was revealed that with the increases of spacing leaf width showed increasing trend. In case of closer spacing plant compete for light and with the time being leaf width decreases.

Statistically significant variation was recorded due to interaction effect of nitrogen and plant spacing in terms of leaf width of lettuce at different growth stages (Table 2). The highest leaf width (13.80, 17.28 and 30.36 cm) at 30, 45 and 60 DAT respectively was found from N_3S_3 which was statistically identical with N_3S_3 at 30, 45 and 60 DAT. The lowest leaf width (8.60, 11.06 and 17.25 cm) at 30, 45 and 60 DAT respectively was obtained from N_0S_1. Data revealed that optimum level of nitrogen and spacing ensured the highest leaf width with maximum vegetative growth.

Fig 1: A general view of lettuce sample.

Table 1: List of treatment combination

Sr. No.	Symbol	Treatment combination
1	T_1	N_0S_1 (Control + Spacing 45 cm × 20 cm)
2	T_2	N_0S_2 (Control + Spacing 45 cm × 25 cm)
3	T_3	N_0S_3 (Control + Spacing 45 cm × 30 cm)
4	T_4	N_1S_1 (60 kg/ha Nitrogen + Spacing 45 cm × 20 cm)
5	T_5	N_1S_2 (60 kg/ha Nitrogen + Spacing 45 cm × 25 cm)
6	T_6	N_1S_3 (60 kg/ha Nitrogen + Spacing 45 cm × 30 cm)
7	T_7	N_2S_1 (120 kg/ha Nitrogen + Spacing 45 cm × 20 cm)
8	T_8	N_2S_2 (120 kg/ha Nitrogen + Spacing 45 cm × 25 cm)
9	T_9	N_2S_3 (120 kg/ha Nitrogen + Spacing 45 cm × 30 cm)
10	T_{10}	N_3S_1 (180 kg/ha Nitrogen + Spacing 45 cm × 20 cm)
11	T_{11}	N_3S_2 (180 kg/ha Nitrogen + Spacing 45 cm × 25 cm)
12	T_{12}	N_3S_3 (180 kg/ha Nitrogen + Spacing 45 cm × 30 cm)

Table 2: Impact of nitrogen and spacing on vegetative growth parameters of lettuce.

	30 DAT				45 DAT				60 DAT			
Treatments	**PH**	**NL/P**	**LL**	**LW**	**PH**	**NL/P**	**LL**	**LW**	**PH**	**NL/P**	**LL**	**LW**
Effect of nitrogen												
N_0	9.93	12.98	11.19	10.48	15.65	21.11	14.56	13.09	22.91	24.42	23.58	21.35
N_1	10.49	14.47	12.29	11.83	19.28	21.97	14.73	14.56	25.92	26.68	23.7	24.19
N_2	10.4	13.2	11.32	10.74	21.75	24.41	15.47	13.2	28.02	24.6	25.42	24.81
N_3	11.97	14.7	13.04	12.78	23.14	24.56	16.67	16.15	29.12	27.39	25.97	28.68
S.Em±	0.33	0.34	0.29	0.31	0.36	0.34	0.32	0.32	0.34	0.27	0.37	0.31
CD at 5%	0.97	1.01	0.85	0.92	1.05	1.0	0.93	0.94	0.99	0.79	1.10	0.94
Effect of spacing												
S_1	9.74	12.94	11.09	10.65	18.71	21.78	13.05	13.65	25.08	24.63	23.75	23.94
S_2	11.02	14.16	12.35	11.75	19.62	23.51	15.64	14.98	27.01	25.54	24.51	24.77
S_3	11.33	14.42	12.44	11.97	21.53	23.78	17.6	15.05	27.38	27.17	25.75	25.1
S.Em±	0.29	0.30	0.25	0.27	0.31	0.29	0.27	0.27	0.29	0.23	0.32	0.27
CD at 5%	0.84	0.88	0.74	0.80	0.91	0.86	0.81	0.81	0.86	0.68	0.95	0.81
Interaction effect of nitrogen and spacing												
N_0S_1	7.94	11.25	9.64	8.6	12.2	18.34	10.05	11.06	18.41	22.36	19.38	17.25
N_0S_2	11.34	13.36	10.67	11.28	14.97	24.28	16.34	13.16	24.97	25.12	25.35	26.5
N_0S_3	10.51	14.34	13.26	12.34	19.78	23.3	17.3	15.38	25.34	26.34	26.37	28.8
N_1S_1	11.56	15.25	13	13.34	19.04	26.6	13	15.08	25.51	28.3	28.39	29.38
N_1S_2	10.78	13.6	11.61	10.08	18.61	22.4	17.37	13.24	26.15	24.38	23.26	22.3
N_1 S_3	9.12	15.25	12.26	12.06	20.19	24.23	13.8	15.36	26.11	27.35	26.25	20.9
N_2S_1	8.97	15.28	13.36	12.66	20.88	25.15	17.35	15.2	27.48	28.36	28	26.69
N_2S_2	10.68	12.26	10.44	9.1	21.79	19.52	17.4	11.64	27.88	22.61	21.38	18.36
N_2S_3	11.54	12.08	10.16	9.68	22.59	18.81	11.65	12.18	28.69	22.37	21.36	19.01
N_3S_1	10.51	14.86	13.4	12.39	22.72	25.04	11.8	15.8	28.94	23.15	22.26	27.08
N_3S_2	12.51	12.54	11.64	12.14	23.11	20.94	19.3	15.38	29.04	26.4	25	28.6
N_3S_3	12.89	16	14.08	13.8	23.58	27.7	19.8	17.28	29.37	32.64	29	30.36
S.Em±	0.57	0.60	0.50	0.54	0.62	0.58	0.55	0.55	0.58	0.46	0.64	0.55
CD at 5%	1.67	1.77	1.47	1.60	1.82	1.72	1.62	1.62	1.72	1.36	1.90	1.62

Note: PH: Plant Height, NL/P: Number of Leaves/Plant, LL: Leaf Length, LW: Leaf Width

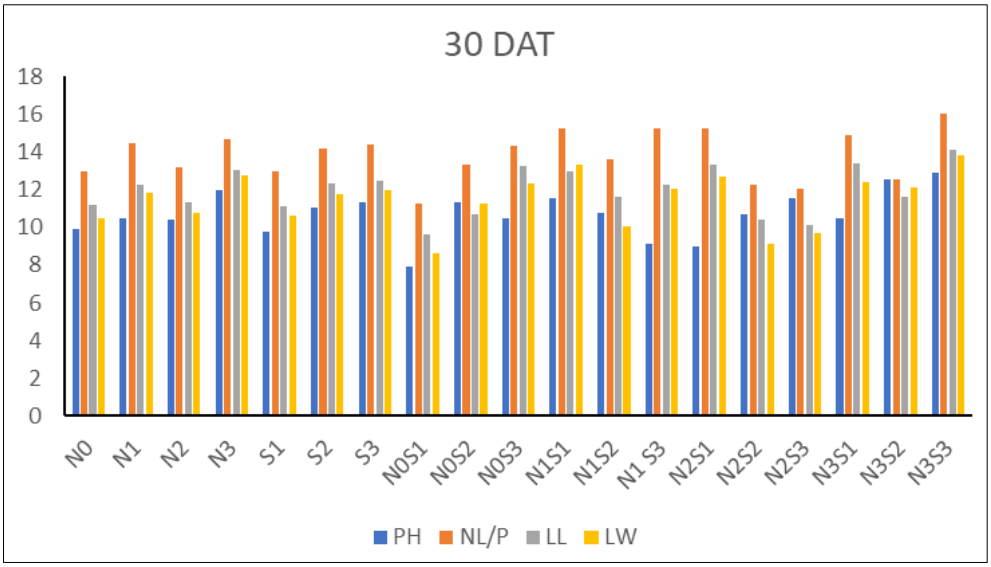

Fig 2: Combined effect of nitrogen and spacing on growth parameters of lettuce at 30 days after transplanting

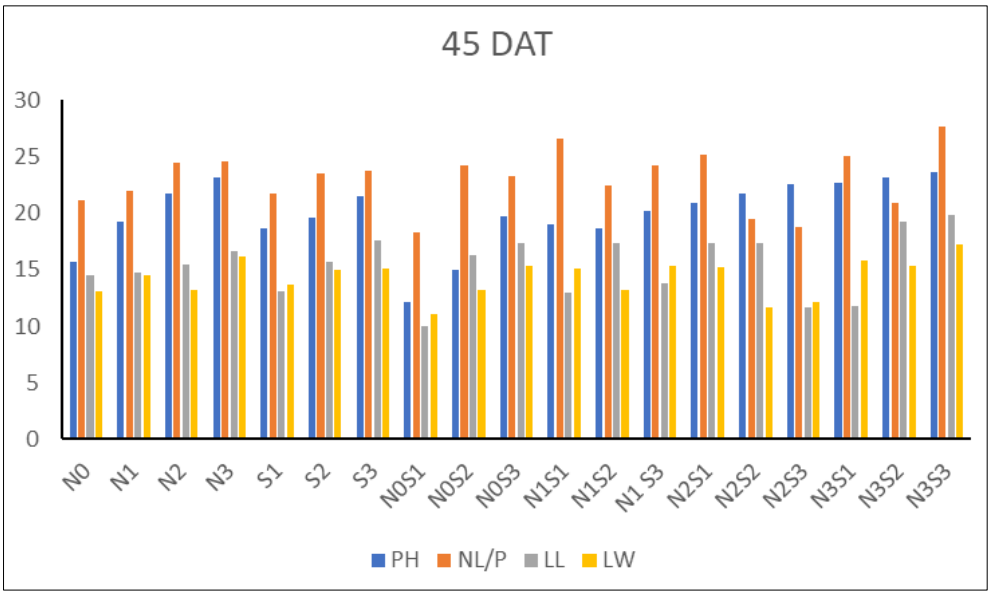

Fig 3: Combined effect of nitrogen and spacing on growth parameters of lettuce at 45 days after transplanting

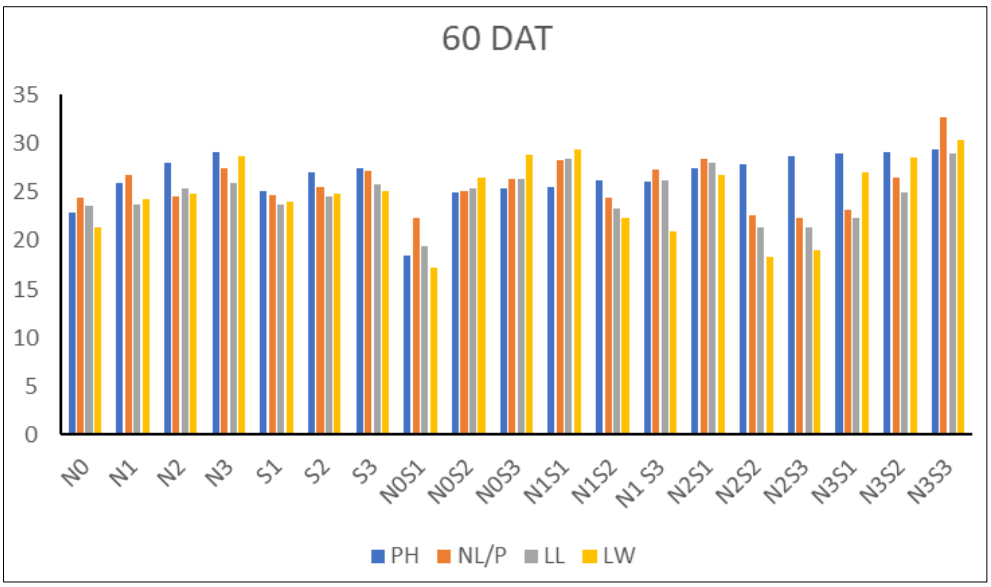

Fig 4: Combined effect of nitrogen and spacing on growth parameters of lettuce at 60 days after transplanting

Conclusion

The above result concluded that nitrogen level and spacing modification effect on growth attributes *viz.*, plant height, number of leaves per plant, leaf length and leaf width of lettuce crop var. 'Great Lakes'. Among the all treatments N_3S_3 combination best for all growth parameters to yield improvement in lettuce.

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