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Research Article

Effect of Different Rates of N and Intrarow Spacing on Growth Performance of Lettuce (*Lactuca sativa* L.) in Gurage Zone, Wolkite University, Ethiopia

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A field experiment was conducted in Wolkite University, Horticulture department practical demonstration site, from February to June 2019 with the objective of determining the optimum level of N and intrarow spacing for better growth of lettuce. The experiment consisted of four levels of N (N0 (0 kg/ha), N1 (50 kg/ha), N2 (100 kg/ha), and N3 (150 kg/ha)) and three levels of intrarow spacing (S1 (15 × 30 cm), S2 (20 × 30 cm), and S3 (25 × 30 cm)). The interrow spacing was maintained as 30 cm. The experiment was laid out in 3 × 4 factorial arrangement in a randomized complete block design (RCBD) and replicated three times. The main effect of nitrogen resulted maximum yield (9.45 ton/ha), dry weight per plant (28.75 g), and fresh weight per plant (57.57 g) which were recorded by the application of 150 kg/ha nitrogen. Likewise, the main effect of intrarow spacing gave maximum yield (8.01 ton/ha), dry weight per plant (21.31 g), and fresh weight per plant (59.15 g) from 25 × 30 cm plant spacing. For interaction effect, the highest yield (10.38 ton/ha), dry weight per plant (50.96 g), and fresh weight per plant (77.88 g) was found from N3S3 (150 kg/ha N and 25 × 30 cm plant spacing). Therefore, in the study, area using 150 kg/ha urea with 25 × 30 cm plant spacing could be advisable for optimum lettuce production.

1. Introduction

Lettuce (*Lactuca sativa* L.), an annual plant of Compositae family, is one of the most important vegetables in human diet. It is normally consumed raw and has a high nutrient value, being rich in calcium, iron, and vitamin A. It is a good source of vitamins and often prescribed to weight-conscious consumers because of its low kilojoules content [1]. The composition of lettuce leaves is approximately 94.3% water, 1.2% protein, 0.2% fat, 2.9% carbohydrate (CHO), 0.7% fiber, and 0.7% ash. It is rich in vitamin A, C, and E and minerals such as calcium, phosphorus, sodium, magnesium, and potassium.

It is an important leafy salad vegetable, rich in vitamins and minerals, that is mainly grown in the cool season of the year in tropical and subtropical countries [2]. The optimum mean temperature range for excellent growth and good quality of lettuce is 15–25°C, and temperature above 25°C accelerates seed stalk and reduces the quality of leaves [3]. It is evident that high air temperature causes high soil temperature, which retards root growth and affects the uptake of water and nutrients and photosynthesis that consequently results in stunted plant growth and mortality [4]. Soil health is a crucial factor for realizing higher yield of vegetables.

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 [5]. Among the various factors, the level of nutrient application and plant spacing is very important factor for lettuce production [6]. Nutrients are used in moderate amounts on lettuce, and there is a need to use with care, especially in the last half to third of the growing season. Excess nitrates late in the growing season tend to cause loose heads. Excess N causes

increased susceptibility of vegetable crops to fungus disease and deterioration of postharvest quality. However, insufficient fertilization retards development, reduces quality, and encourages bolting in lettuce [7].

Lettuce is a newly introduced crop in Ethiopia, and its production package is almost unknown. To achieve optimum production, the management of this vegetable, such as spacing and nutrients, is very important. Lettuce yield usually varies with different plant densities. Spacing influences average fresh weight, number of heads, and yield at harvest [8]. Verker and Spitters [6] stated that plant spacing is an important factor for lettuce seed production. The improper plant spacing may cause either too dense or too sparse population, resulting in the reduction of lettuce yield. But optimum plant density ensures the plants to grow uniformly and properly through efficient utilization of moisture, nutrients, and light and thus causes to produce maximum yield of lettuce. Planting lettuce with proper spacing increases yield, quality, and vigorous growth. Therefore, this research was initiated with the objective of evaluating the effect of N and intrarow spacing on the growth performance of lettuce.

2. Material and Methods: Description of the Study Area

The study was conducted at the Wolkite University Agriculture and Natural Resource research site in 2019. Wolkite, the capital city of Gurage zone, is 170 km away from Addis Ababa to the southwest direction. Wolkite comprises an altitude ranging from 1300 meters above sea level. The mean annual temperature ranges from 14 to 24°C with an average of 20–25°C. The soil type of the area heavy vertisol is around 80%, which is rich in organic matter, while there is less capability to drain water. The rain fall of Wolkite is bimodal in which 80% of rain falls in the winter period of June to August whereas 20% in the belg period of February to May [9].

2.1. Experimental Material. Seeds of lettuce variety called "Great Lake" and urea fertilizer as a source of nitrogen (N) fertilizer were used for this study.

2.2. Treatments and Experimental Design. The treatment consisted of 4 × 3 factorial combinations of N (0, 50, 100, and 150 kg/ha) and intrarow plant spacing (15 × 30, 20 × 30 and 25 × 30 cm). Interrow spacing was maintained 30 cm for all treatments. The experiment was laid out in a randomized complete block design in a factorial arrangement and replicated three times. Thus, there were 12 treatment combinations which account for 36 experimental plots. Raised plots were prepared with a size of 1.2 m by 1.5 m in width and length, respectively. Spacing of 0.5 m between plots and 0.8 m between blocks was maintained for cultural operations. Plants in the middle two rows were used for data collection, leaving aside those at the border rows as well as those at both ends of each row.

2.3. Seed Bed Preparation and Transplanting

2.3.1. Seed Bed Preparation. The nursery bed was prepared by pulverizing the soil very well. The seeds were sowed at a depth of 2 cm and covered lightly with soil. After that, the nursery bed was covered with a thin layer of mulch. The nursery bed was watered, and soil moisture was kept at field capacity. The bed was shaded to protect the young plants from direct sunlight and strong wind.

2.3.2. Transplanting. Seedlings were watered about an hour before uprooting them from the nursery, in order to prevent root damages. Transplanting was done late in the afternoon when the sun was cool. The experimental field was ploughed about a month in advance. For proper drainage and root development, the beds were raised at a height of 5 cm. Beds were watered, and seedlings were planted at the same depth while in the nursery.

2.4. Field Management. All agronomic practices were applied according to the standard practices recommended for the lettuce crop.

2.5. Data Collection

2.5.1. Plant Height (cm). It was measured from the ground level to the topmost growth point above the ground after the plants reached maximum vegetative stage by using a ruler.

2.5.2. Leaf Length (cm). It was measured by using a ruler. The measurements were taken from the base (end of sheath) to the tip of the three leaves of each plant. The average length of leaves was taken from six selected plants in centimeter (cm).

2.5.3. Number of Leaves Per Plant. Visual counting of leaf on randomly taken plants was recorded for each plant by using our hands. Every visible leaf on the plant, including the tips of new leaves, was counted.

2.5.4. Leaf Width (cm). It was measured at the broadest part of the leaves by using the ruler. Three leaves were measured from each of the six sampled plants, and an average was taken.

2.5.5. Root Length (cm). It was measured from middle rows of the plot, and length was measured in centimeter by using the ruler.

2.5.6. Fresh Weight Measuring (g). Plants were removed from soil and washed off any loose soil, and they were blotted gently with soft paper to remove any free-surface moisture and weighed immediately by using a sensitive balance.

2.5.7. Dry Weight Measuring (g). The plants were removed from the soil and washed off any loose soil, and they were blotted to remove any free-surface moisture. The plants were dried in an oven set to low heat (75°C) overnight and were cooled in a dried environment. Once the plants were cooled, we weighed them on a scale (gram).

2.6. Data Analysis. All variables were subjected to the analysis of variance using GenStat (version 13.0) software. Significant treatment means were separated using least significance difference (LSD) at 5%.

3. Results and Discussion: Leaf Length

The main effect of N showed that the leaf length had significant difference for lettuce. The highest (23.12 cm) and the lowest (11.06 cm) leaf length was recorded by applying 150 kg/ha and 0 kg/ha N, respectively (Table 1). Higher dose of nitrogen caused higher leaf length. This is because higher amount of nitrogen fertilizer increased the vegetative growth of lettuce. Boroujerdnia and Ansari [10] and Hasan et al. [11] found similar result with this result. Similarly, the main effect of spacing significantly affected leaf length. Significant difference was observed between S1, S2, and S3. The highest leaf length (18.35 cm) was recorded from S2, and the lowest was 16.25 cm from S1. The result of the experiment also showed that the interaction effect significantly affected the leaf length of lettuce. The highest leaf length 25.94 cm was found from N3S2 (150 kg/ha N and 20 × 30 cm) followed by 22.67 cm from N3S3 (150 kg/ha and 25 × 30 cm) (Table 1). The lowest leaf length (10.58 cm) was obtained from N0S2 (0 kg/ha N and 20 × 30 cm). Nonsignificant variation was observed between N2S3, N3S1, and N3S2. Increasing the level of N in wider spacing resulted higher leaf length. Moreover, lower leaf length was observed from low N levels in closer spacing. This result is in line with the work of Hasan et al. [11] who observed that the optimum level of nitrogen and plant spacing ensured the highest leaf length with maximum vegetative growth.

Table 1: Effect of N and intrarow spacing on leaf length and leaf number per plant of lettuce.

Factors	Treatment		Leaf length (cm)	Leaf number
Nitrogen	0 kg/ha	(N0)	11.06[a]	15.40[a]
	50 kg/ha	(N1)	14.96[b]	17.68[b]
	100 kg/ha	(N2)	20.50[c]	18.76[c]
	150 kg/ha	(N3)	23.12[d]	16.66[c]
	LSD (0.05)		**0.608**	**0.430**
Spacing	15 × 30 cm	(S1)	16.25[a]	16.03[a]
	20 × 30 cm	(S2)	18.35[b]	17.44[b]
	25 × 30 cm	(S3)	17.62[c]	19.40[c]
	LSD (0.05)		**0.526**	**0.372**
Nitrogen* spacing	N0S1		11.22[a]	14.31[a]
	N0S2		10.58[a]	17.39[a]
	N0S3		11.37[a]	14.51[a]
	N1S1		15.89[b]	15.02[b]
	N1S2		14.47[b]	16.68[b]
	N1S3		14.51[c]	21.33[b]
	N2S1		17.16[d]	18.10[bc]
	N2S2		22.41[e]	18.49[cd]
	N2S3		21.92[f]	19.70[d]
	N3S1		20.74[f]	16.70[e]
	N3S2		25.94[f]	17.22[f]
	N3S3		22.67[g]	22.06[f]
	LSD (0.05)		**1.052**	**0.745**

Means followed by the same letter within a column are not significantly different from each other at 5% level of significance.

3.1. Number of Leaves/Plants. Analysis of the result showed that both the main and interaction effects significantly affected the number of leaves per plant of lettuce. In case of main effect of nitrogen, the maximum number of leaves (18.76) was observed by the application of 100 kg/ha N, whereas the minimum was recorded from the control (0 kg/ha N) treatment (Table 1). Application of 100 kg/ha and 150 kg/ha N gave statistically similar result. Optimum level of N results optimum number of leaves. This is because N favors good development of chlorophyll, and it increases the rate of photosynthesis. Hence, it increases the number of leaves. The main effect of spacing also significantly affected the number of leaves per plant of lettuce. With the increase of spacing, the number of leaves per plant also increased. The highest number of leaves (19.40) was recorded from S3 (25 × 30 cm) which was followed by 17.44 cm from S2 (20 × 30 cm) and 16.03 cm from 15 × 30 cm. Wider spacing allows space for vertical and horizontal expansion of leaves so that it leads for production of a greater number of leaves per plant than closer spacing. Interaction effect of nitrogen and plant spacing showed significant difference between treatments. The maximum and minimum number of leaves per plant was recorded as 22.06 and 14.51 which are obtained from N3S3 (150 kg/ha N and 25 × 30 cm spacing) and N0S1 (0 kg/ha N and 15 × 30 cm spacing), respectively (Table 1). N1S3 gave maximum (21.33) number of leaves per plant that showed significant variation form N1S3.

3.2. Leaf Width. The leaf width was significantly influenced by the main effects of nitrogen and intrarow spacing ($P < 0.001$). However, the interaction effect of N and spacing showed nonsignificant variation.

The analysis of variance indicated that N significantly affected the leaf width of lettuce. The main effect of N showed that the maximum leaf width (11.22 cm) was observed by the application of 150 kg/ha N, and it is about 35% higher than the control. Similarly, the highest leaf width (10.88 cm) was recorded using the spacing 25 × 30 cm, which is 33% higher than the control treatment (Table 2). Application of 100 kg/ha and 150 kg/ha N showed statistically similar result. The main effect of spacing showed that the maximum leaf width (10.88 cm) was recoded on spacing of 25 × 30 cm. Similarly, the minimum leaf width was recorded on spacing of 15 × 30 cm. This result may be attributed to the fact that wider plant spacing showed less competitive for light, water, mineral, and air.

3.3. Plant Height. The plant height was significantly influenced by the main effects of nitrogen and intrarow spacing ($P < 0.001$). On the other hand, the interaction effects showed nonsignificant difference.

The main effect of nitrogen significantly affected the plant height of lettuce. The maximum plant height (17.78) was observed by the application of 150 kg/ha N, and it is about 22% higher than the control (Table 3). Similarly, the highest plant height (17.27 cm) was obtained using the spacing 25 × 30 that is 21% higher than the control treatment. This might be due to the fact that wider spacing reduces competition between plants for nutrients, light, and moisture and enhances growth. Nitrogen is a constituent of chlorophyll, and an increase in N content might have increased photosynthesis, leading to better vigor [12]. However, narrow-spaced treatments gave shorter height (13.69 cm). Moniruzzaman [13] reported similar findings from the closest spacing.

3.4. Root Length. Application of different levels of nitrogen showed statistically significant variation for the root length of lettuce. Both main effect of spacing and interaction effect of nitrogen and intrarow spacing did not show significant variation for root length. The result showed that higher doses of nitrogen cause deeper root length of lettuce. The maximum root length was 12.57 cm found from the application of 150 kg/ha N which was 21.32% higher than the control treatment (Table 4).

3.5. Leaf Fresh Weight. The result of this study showed that both the main effect and the interaction effect of nitrogen and intrarow spacing were significantly affected the fresh weight of lettuce. The main effect of nitrogen showed significant variation except application of nil N and 50 kg/ha N which did not show variation between themselves. The highest leaf fresh weight was 57.57 g by application of 150 kg/ha N, whereas the lowest (37.07 g) was from the untreated treatment (Table 5). This might be because nitrogen can increase the vegetative growth of the plant and so fresh weight. This result is in line with that of Tittonell et al. [14] who showed that increasing nitrogen fertilizer from 0–150 kg ha^{-1} increased the fresh weight of the crop. The fresh weight of lettuce also showed statistically significant variation due to intrarow spacing. The highest fresh weight was 59.15 g from 25 × 30 cm intrarow spacing, whereas the lowest was 35.97 g from 15 × 30 cm spacing. It was revealed that, with the increase of intrarow spacing, the fresh weight of plant showed increasing trend [11]. In case of wider intrarow spacing, the plant received enough light and nutrients which leads to attain maximum fresh weight. Moreover, the interaction effect of nitrogen and intrarow spacing showed statistically significant variation for fresh weight. The maximum fresh weight per plant (77.88 g) was found from N3S3 (150 kg/ha N and 25 × 30 cm intrarow spacing), and the minimum was 26.84 g from the N0S1 (nil N and 15 × 30 cm intrarow spacing). The result showed that, with the increasing level of nitrogen and intrarow spacing, it ensured maximum vegetative growth that ensured highest fresh weight per plant.

Table 2: Main effect of nitrogen and intrarow spacing on the leaf width of lettuce.

Factor	Treatment	Leaf width (cm)
N (kg/ha)	0	7.3[a]
	50	9.22[b]
	100	10.5[c]
	150	11.22[c]
LSD (5%)		1.126
Spacing (cm)	15 × 30	8.27[a]
	20 × 30	9.52[b]
	25 × 30	10.88[c]
LSD (5%)		0.976
CV (%)		12.1

Means followed by the same letter within a column are not significantly different from each other at 5% level of significance.

Table 3: Main effect of nitrogen and intrarow spacing on plant height of lettuce.

Factor	Treatment	Plant height (cm)
N (kg ha^{-1})	0	13.79[a]
	50	15.17[a,b]
	100	15.97[b]
	150	17.78[c]
LSD (5%)		1.505
Spacing (cm)	15 × 30	13.69[a]
	20 × 30	16.07[b]
	25 × 30	17.27[b]
LSD (5%)		1.303
CV (%)		12.1

Means followed by the same letter within a column are not significantly different from each other at 5% level of significance.

Table 4: Main effect of nitrogen on root length.

Factor	Treatment	Root length (cm)
N (kg/ha)	0	9.89[a]
	50	11.9[a]
	100	11.97[b]
	150	12.57[b]
LSD (5%)		1.414
CV (%)		12.48

*means followed by the same letter within a column are not significantly different from each other.

3.6. Dry Weight. The main effects of different levels of nitrogen significantly influenced dry weight per plant. The maximum (28.75 g) and the minimum (7.05 g) dry weight per plant was obtained from 150 kg/ha N and 0 kg/ha N, respectively (Table 5). With the increase of nitrogen application, the dry weight per plant increases due to more availability of nutrients among the plants during vegetative growth and later caused accumulation of metabolites. Tittonell et al. [14], Mahmoudi Kliber [15], and Hasan et al. [11] showed similar results with this result. Dry weight per plant of lettuce showed statistically significant variation due to intrarow spacing. The maximum

Table 5: Effect of N and intrarow spacing on fresh weight/plant, dry weight/plant, and yield of lettuce.

Factors	Treatment	Fresh weight (g)	Dry weight (g)	Yield (ton/ha)
Nitrogen	0 kg/ha (N0)	37.07^{a}	7.05^{a}	6.14^{a}
	50 kg/ha (N1)	41.88^{a}	9.86^{ab}	7.17^{b}
	100 kg/ha (N2)	50.82^{b}	12.96^{b}	8.05^{c}
	150 kg/ha (N3)	57.57^{c}	28.75^{c}	9.45^{d}
	LSD (0.05)	**4.877**	**4.675**	**0.318**
Spacing	15 × 30 cm (S1)	35.97^{a}	9.27^{a}	7.54^{a}
	20 × 30 cm (S2)	45.39^{b}	13.38^{b}	7.57^{a}
	25 × 30 cm (S3)	59.15^{c}	21.31^{c}	8.01^{b}
	LSD (0.05)	**4.224**	**4.049**	**0.275**
Nitrogen * spacing	N0S1	26.84^{a}	4.36^{a}	5.96^{a}
	N0S2	36.60^{ab}	7.54^{ab}	6.10^{a}
	N0S3	47.78^{ef}	9.25^{ab}	6.37^{a}
	N1S1	31.95^{ab}	9.38^{ab}	7.10^{b}
	N1S2	42.70^{cde}	9.87^{ab}	7.12^{b}
	N1S3	50.98^{ef}	10.32^{ab}	7.28^{bc}
	N2S1	46.14^{de}	10.77^{ab}	8.43^{ef}
	N2S2	46.36^{de}	13.40^{b}	7.73^{bc}
	N2S3	59.98^{g}	14.72^{bc}	8.00^{de}
	N3S1	38.94^{bcd}	12.57^{b}	8.65^{f}
	N3S2	55.90^{fg}	22.71^{c}	9.32^{g}
	N3S3	77.88^{h}	50.96^{d}	10.38^{h}
	LSD (0.05)	**8.448**	**8.097**	**0.550**

Means followed by the same letter within a column are not significantly different from each other at 5% level of significance.

(21.31 g) dry weight per plant was recorded from 25 × 30 cm intrarow spacing, and the minimum (7.05 g) was from 15 × 30 cm. It was revealed that, with the increase of intrarow spacing, the dry weight of the plant showed increasing trend because of less competition for nutrients. The interaction effect of nitrogen and intrarow spacing significantly influenced dry weight per plant of lettuce. The maximum (50.96 g) dry weight per plant was found from N3S3 (150 kg/ha N and 25 × 30 cm intrarow spacing), whereas the minimum (4.36 g) dry weight per plant was recorded from N0S3 (0 kg/ha N and 15 × 30 cm intrarow spacing) (Table 5). It was revealed that, with increased level of nitrogen and plant spacing, it ensured maximum vegetative growth that ensured highest dry weight per plant.

3.7. Yield of Lettuce. The analysis of this result showed that both the main effects and the interaction effects of nitrogen and intrarow spacing significantly ($P < 0.001$) influenced the yield of lettuce. Different levels of nitrogen application influenced the yield of lettuce (Table 5). The highest yield due to the effect of nitrogen was 9.45 ton/ha by the application of 150 kg/ha which is 35% higher than the untreated treatment. There was no significant variation between the levels of nitrogen. This might be because increased nitrogen helps the plant for vegetative growth that later contributes for maximized yield. Plant spacing also showed significant variation to the yield of lettuce. The maximum (8.01 ton/ha) and the minimum (7.54 ton/ha) yield due to spacing was obtained from 25 × 30 cm and 15 × 30 cm intrarow spacing, respectively. This result is in line with that of Hasan et al. [11] who showed that, with the increase of spacing, the individual weight per plant increased. Total yield/ha may be higher due to higher individual plant weight and wider spacing ensuring the highest yield with maximum vegetative growth.

The interaction effect of nitrogen and plant spacing were significantly influenced the yield of lettuce. The highest yield (10.38 ton/ha) was found from N3S3 (150 kg/ha N and 25 × 30 cm intrarow spacing) and the lowest (5.96 ton/ha) was found from N0S1 (0 kg/ha N and 15 × 30 cm intrarow spacing).

4. Conclusions

Results of the experiment showed that the plant height and leaf width were significantly influenced by the main effect of both nitrogen and plant spacing. The main effect of nitrogen resulted the maximum plant height (17.78 cm), leaf width (11.22 cm), fresh weight per plant (57.57 g), dry weight per plant (28.75 g), and yield (9.45 ton/ha) which were recorded by the application of 150 kg/ha. Similarly, the main effect of spacing resulted the maximum plant height (17.27 cm), leaf width (10.88 cm), fresh weight per plant (59.15 g), dry weight per plant (21.31 g), and yield (8.01 ton/ha) which was obtained from the spacing of 25 × 30 cm. In case of the interaction, effects of maximum fresh weight per plant (77.88 g), dry weight per plant (50.96 g), and yield (10.38 ton/ha) were obtained from N3S3. Therefore, in the study, area using 150 kg/ha urea with 25 × 30 cm plant spacing could be advisable for optimum lettuce production.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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