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Impact of planting spacing and nitrogen content on lettuce *(Lactuca sativa* L.) growth, yield, and quality

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Abstract
The present study was conducted at the Instructional-Cum-Research Farm, Department of Horticulture, College of Agriculture, Latur, V.N.M.K.V., Parbhani, during the Rabi season of 2024-2025. The field experiment followed a Factorial Randomized Block Design (FRBD) with three replications. The treatments consisted of three nitrogen levels: N1 (100 kg N/ha), N2 (125 kg N/ha), and N3 (150 kg N/ha), combined with three plant spacings: S1 (30 × 15 cm), S2 (30 × 30 cm), and S3 (45 × 30 cm). This resulted in nine treatment combinations applied in a factorial arrangement. The lettuce variety 'Iceberg' was selected for the study. The experiment aimed to evaluate the impact of planting spacing and nitrogen levels on the growth, yield, and quality of lettuce (*Lactuca sativa* L.). The key findings from the treatments are summarized below.
Nitrogen application had a significant influence on several growth and quality parameters of lettuce, including plant height (19.02 cm), fresh leaf weight per plant (23.51 g), dry matter content (2.93%), fiber content (2.23%), and chlorophyll concentration (45.38 mg/100g) at the N2 level (125 kg N/ha). However, nitrogen did not significantly affect the number of leaves per plant (14.70), leaf area (289.14 cm²), yield per plant (288.82 g), yield per plot (4.95 kg), gross yield (81.92 q/ha), marketable yield (81.61 q/ha), or the incidence of thrips (11.92%) and mosaic disease (8.14%).
Planting spacing also had a notable effect on various traits at the S2 spacing level (30 × 30 cm), including plant height (19.18 cm), fresh leaf weight per plant (25.31 g), yield per plant (293.28 g), yield per plot (5.09 kg), gross yield (84.27 q/ha), marketable yield (83.74 q/ha), fiber content (2.19%), chlorophyll concentration (45.40 mg/100g), and the incidence of thrips (11.29%) and mosaic disease (8.06%). In contrast, spacing had no significant impact on the number of leaves per plant (14.48), leaf area (312.71 cm²), or dry matter content (2.89%).
In conclusion, both nitrogen application and planting spacing significantly influenced the growth, yield, and quality of lettuce during the Rabi season. The combination of 125 kg N/ha with a planting spacing of 30 × 30 cm proved to be the most effective strategy for maximizing lettuce performance in the Marathwada region.

Keywords: Lettuce, Iceberg, growth, yield, percentage, *Lactucasativa* L., nitrogen

1. Introduction
Lettuce (*Lactuca sativa* L.) is one of the most important vegetables cultivated commercially worldwide, appreciated for its unique flavor and texture. This annual leafy herb belongs to the family *Compositae* and has a chromosome number of 2n = 2x = 18. It is believed to have originated in the Mediterranean region, Central Asia, and Southwest Asia. Primarily used in salads and soups, lettuce is occasionally cooked and is known for its delicate, crisp texture and mildly bitter taste. Cultivated lettuce varieties have evolved from wild or prickly lettuce (*Lactuca serriola L.*), including a primitive form referred to as oil-seed lettuce (Boukema *et al.*, 1990) [6].
Lettuce thrives in cool climates and is predominantly grown in temperate regions or areas with mild winters and cooler summers, particularly in subtropical zones. Optimal temperatures for lettuce cultivation range from 18-25°C during the day and 10-15°C at night (Ryder, 1998) [26].
In India, as of 2023, lettuce was cultivated over an area of 15.33 thousand hectares, yielding approximately 355.48 million tonnes. The primary states engaged in its cultivation include Maharashtra, Himachal Pradesh, Uttarakhand, and parts of Karnataka.

Nutritionally, lettuce is a rich source of vitamin A, calcium, iron, protein, carbohydrates, and vitamin C. A 100 g edible portion contains 0.09 mg thiamine, 0.13 mg riboflavin, 0.3 g fat, 0.5 g fiber, 1.2 g minerals, 2.1 g protein, 2.5 g carbohydrates, 2.6 mg iron, 10.0 mg vitamin C, 80 mg phosphorus, 93.4 g moisture, 310 mg calcium, and approximately 1650 I.U. of vitamin A. Owing to its pleasant taste and high content of nutraceutical compounds, leafy lettuce plays a significant role in human nutrition (Kim *et al.*, 2016) [24].

Lettuce offers numerous health benefits, including cholesterol reduction, and exhibits anti-inflammatory, antioxidant, antimicrobial, and anti-cancer properties. It also aids in improving sleep and managing anxiety. These health-promoting effects are largely attributed to the presence of bioactive terpenoids and polyphenols, such as carotenoids, phenolic acids, and flavonoids. In India, lettuce is gaining popularity due to shifting dietary preferences and increased demand for nutritious foods that promote health and longevity. It also possesses medicinal properties, acting as an anodyne, sedative, diuretic, and expectorant (Kallo, 1986) [21].

Lettuce is primarily cultivated during the winter season. In Jordan, two major types are grown: Iceberg and Romaine. Iceberg lettuce, also known as Crisphead, forms dense, compact heads with crisp, pale green leaves and is popular in the fresh market due to its durability during transport and storage (Dehpande and Salunkhe, 1998; Armstrong, 2002; Relf and McDaniel, 2000) [3, 27, 28]. Romaine (Cos) lettuce, characterized by upright, cylindrical heads and long, wavy leaves, is both nutritious and relatively easy to cultivate (Armstrong, 2002) [3].

However, many Crisphead varieties are not tolerant to heat and tend to bolt at temperatures above 23°C during the day and 7°C at night (Jackson *et al.*, 1996a,b) [19], reducing their market value. Early spring or fall transplanting is recommended to take advantage of cooler weather. Bolting due to high temperatures can lead to bitterness, loose heads, and increased incidence of tip burn (Jackson *et al.*, 1996a,b) [19]. Off-season planting often results in non-heading, puffiness, or bolting (Jackson *et al.*, 1996a) [19].

The ideal day/night temperatures for optimal growth in both Iceberg and Romaine lettuce are 23°C and 7°C, respectively. Dense head formation in Iceberg lettuce is associated with cooler conditions around the heading stage (Wurr *et al.*, 1992) [29]. Head weight of the cultivar 'Saladin' increased with later transplanting, peaking in crops transplanted on May 29 (6.2-15.4°C) or June 12 (7.3-17°C) (Wurr *et al.*, 1987) [30]. Plants grown under ambient conditions produced the heaviest heads, while those grown at 20:10°C had lighter heads. Under floating hydroponics, the highest dry mass was recorded at 24°C (Thompson and Langhans, 1998) [31]. Conversely, higher temperatures prior to heading led to reduced head size. The optimum average temperature for maximum head weight in Iceberg lettuce is approximately 12°C. Lettuce is a relatively new leafy vegetable in India, with growing popularity due to its nutritional value and market potential. Nitrogen application and plant spacing are critical for the optimal growth, development, and yield of lettuce. However, limited research has been conducted on these factors in Maharashtra. Farmers generally rely on traditional practices for fertilizer application and spacing, which may not be optimal. Therefore, the present investigation aims to evaluate the effects of nitrogen levels and planting distances to improve crop performance and support informed cultivation practices.

Objectives

1. To study the effect of nitrogen level on growth, yield and quality of lettuce.
2. To study the effect of planting spacing on growth, yield and quality of lettuce.

2. Materials and Methods

The present experiment was conducted during the Rabi season of 2024 at the Instructional-cum-Research Farm, Department of Horticulture, College of Agriculture, Latur, V.N.M.K.V., Parbhani. The materials used and the methodologies adopted during the course of the investigation are detailed in this chapter under appropriate subheadings.

The research was carried out under the auspices of the Department of Horticulture, College of Agriculture, Latur, V.N.M.K.V., Parbhani. Geographically, Latur is located between 18°05′ to 18°75′ North latitude and 76°25′ to 77°25′ East longitude. The region falls under the semi-arid and tropical agro-climatic zone of Maharashtra and lies at an elevation ranging from 540 to 634 meters above mean sea level (MSL).

The experiment utilized seeds of the lettuce cultivar ‘Iceberg’ and was laid out in a Factorial Randomized Block Design (FRBD) with three replications. The study included two factors:

Factor A - Nitrogen levels

N_1: 100 kg N/ha
N_2: 125 kg N/ha
N_3: 150 kg N/ha

Factor B - Plant spacing

S_1: 30 × 15 cm
S_2: 30 × 30 cm
S_3: 45 × 30 cm

A total of nine treatment combinations were tested: S_1N_1, S_1N_2, S_1N_3, S_2N_1, S_2N_2, S_2N_3, S_3N_1, S_3N_2, and S_3N_3. In total, 27 plots were established, each measuring 3 × 2 meters. A spacing of 1.0 meter was maintained between blocks, while individual plots were separated by 0.5 meter.

2.1 Treatment details

A) Factor A - Nitrogen level (N)	B) Factor B - Planting spacing (cm)
N_1 - 100 kg/ha	S_1 - 30 × 15 cm
N_2 - 125kg/ha	S_2 - 30 × 30 cm
N_3 - 150 kg/ha	S_3 - 45 × 30 cm

2.2 Treatment Combination

Sr. No	Treatment	Planting spacing	Nitrogen (kg ha^{-1})
1	S_1N_1	30×15cm	100kg N/ha
2	S_1N_2	30×15cm	125kg N/ha
3	S_1N_3	30×15cm	150kg N/ha
4	S_2N_1	30×30cm	100kg N/ha
5	S_2N_2	30×30cm	125kg N/ha
6	S_2N_3	30×30cm	150kg N/ha
7	S_3N_1	45×30cm	100kg N/ha
8	S_3N_2	45×30cm	125kg N/ha
9	S_3N_3	45×30cm	150 kg N/ha

3.1 Methodology

3.2 Cultural Practices

3.2.1 Land Preparation

The experimental site was brought to a fine tilth through ploughing, clod crushing, and criss-cross harrowing. The area was then demarcated into raised beds measuring 3 × 2 m, with 1 m spacing between replications and 0.5 m between individual plots.

3.2.2 Raising of Seedlings

Seeds were sown in protrays at the rate of one seed per cell. After sowing, seeds were covered with cocopeat, and the trays were stacked and covered with a polythene sheet to maintain humidity until germination. Germination began after 6-7 days, at which point the trays were placed individually on raised beds inside a shade net house. The 30-day-old seedlings were transplanted into the experimental field on 30th December 2024.

3.2.3 Fertilizer Application

A uniform basal dose of 60 kg K_2O ha^{-1} and 60 kg P_2O_5 ha^{-1} was applied before transplanting. Nitrogen was applied as per treatment: once at transplanting and again 30 days after transplanting.

3.2.4 Irrigation

Light irrigation was given immediately after transplanting, followed by another irrigation 4-5 days later. Subsequent irrigations were applied based on crop requirements.

3.3 Observations Recorded

Five representative plants were randomly selected from each of the 27 plots. The average values from these five plants were used for statistical analysis to study the effect of nitrogen levels and planting spacing on the growth, yield, and quality of lettuce. The details of the observations and techniques used are provided below:

3.3.1 Growth Parameters

3.3.1.1 Plant Height (cm)

Plant height was measured from the ground level to the tip of the longest leaf (held vertically) at 20 days, 40 days, and at harvest. The average plant height from five plants per treatment across three replications was calculated and expressed in centimeters (cm).

3.3.1.2 Number of Leaves per Plant

Fully developed green leaves were counted at 20 days, 40 days, and at harvest. The average number of leaves per plant was calculated.

3.3.1.3 Leaf Area (cm²)

Leaf area was calculated based on the length and width of leaves from five randomly selected plants and expressed in square centimeters (cm²).

4.3.1.4 Fresh Weight of Leaves per Plant (g)

At harvest, leaves were detached from each sampled plant using a sharp knife, and the average fresh weight per plant was recorded in grams (g).

4.3.2 Yield Parameters

4.3.2.1 Yield per Plant (g)

Five randomly selected plants were harvested (cut above ground level), and the fresh weight of each head was measured using a digital balance. The mean yield per plant was expressed in grams (g).

3.3.2.2 Yield per Plot (kg)

The total fresh weight of lettuce heads harvested from each treatment and replication was recorded, and the average yield per plot was calculated in kilograms (kg).

3.3.2.3 Gross Yield (q ha^{-1})

Harvested lettuce heads from the net plot area were weighed, and the yield was expressed in kg per plot. This value was extrapolated to obtain the estimated gross yield per hectare and expressed in quintals per hectare (q ha^{-1}).

3.3.2.4 Marketable Yield (q ha^{-1})

Only quality lettuce heads were considered for marketable yield. The total marketable yield per plant was converted to a per hectare basis and expressed in quintals per hectare (q ha^{-1}).

3.3.3 Quality Parameters

3.3.3.1 Dry Matter Content (%)

A 100 g leaf sample was finely chopped and sun-dried, followed by oven drying at 70°C for 72 hours. After drying, the samples were cooled in a desiccator to room temperature, and the dry weight was recorded. Dry matter content was calculated using the formula:

$$\text{Dry Matter (\%)} = \frac{\text{Dry Weight}}{\text{Fresh Weight of Leaves}} \text{ x } 100$$

3.3.3.2 Chlorophyll Content (mg/100 g)

Chlorophyll was extracted by treating fresh leaf tissue with dimethyl sulfoxide (DMSO). Absorbance was measured at 645 nm and 663 nm, and total chlorophyll content was calculated using the formula:

$$\text{Total Chlorophyll (mg/100 g)} = \frac{\text{Z x Vol. Of extract x 100}}{\text{1000 x weight of plant sample (g)}}$$

4. Results and Discussion

4.1.1 Effect of nitrogen level and planting spacing on plant height (cm)

Data on plant height was presented in Table 3.1.

4.1.1.1 Effect of Nitrogen

The application of nitrogen at the rate of N_2 (125 kg N ha^{-1}) had a non-significant effect on plant height at 20 DAT (13.50 cm) and at harvest (19.02 cm). However, a significant effect was observed at 40 DAT, where the N_2 treatment outperformed other nitrogen levels. This indicates that nitrogen availability at this stage played a crucial role in promoting cell division and elongation, contributing to enhanced plant growth and development. Similar findings were reported by Darshan *et al.* (2019) [8].

4.1.1.2 Effect of Planting Spacing

Planting spacing had a significant effect across all tested spacings: S_1 (30 × 15 cm), S_2 (30 × 30 cm), and S_3 (45 × 30 cm). The observed differences were mainly due to the wider spacing, which allowed better light penetration and resource availability during the early growth stages. These findings are consistent with previous studies by Prasad *et al.* (2009) on Chinese cabbage and Yadav *et al.* (2012) on cabbage [32, 33].

3.1.1.3 Combined Effect of Nitrogen Level and Planting Spacing

The combined effect of nitrogen levels and planting spacing on plant height was found to be non-significant.

Table 3.1: Effect of nitrogen level and planting spacing on planting height (cm)

Treatment	20 DAT	40 DAT	At harvest
Nitrogen Level			
N_1	12.78	18.22	18.36
N_2	13.50	18.84	19.02
N_3	12.44	17.82	18.22
SE ±	0.297	0.25	0.27
C. D. at 5%	NS	S	NS
Planting Spacing (cm)			
S_1	13.28	18.16	18.29
S_2	13.44	19.03	19.18
S_3	12.00	17.70	18.13
SE ±	0.297	0.25	0.27
C. D. at 5%	S	S	S
Interaction(NxP)			
SE(m)±	0.53	0.43	0.47
CDat5%	NS	NS	NS
General mean	7.08	4.10	4.42

4.1.2 Effect of Nitrogen Level and Planting Spacing on Number of Leaves per Plant

Data on the number of leaves per plant recorded at various growth stages are presented in Table 3.2.

4.1.2.1 Effect of Nitrogen

The effect of nitrogen was found to be non-significant across all levels: N_1 (100 kg N ha^{-1}), N_2 (125 kg N ha^{-1}), and N_3 (150 kg N ha^{-1}). There were no notable differences in the number of leaves per plant among the nitrogen treatments.

4.1.2.2 Effect of Planting Spacing

The effect of planting spacing was also found to be non-significant for all spacing levels: S_1 (30 × 15 cm), S_2 (30 × 30 cm), and S_3 (45 × 30 cm). Spacing did not influence the number of leaves per plant to a statistically significant extent.

4.1.2.3 Combined Effect of Nitrogen Level and Planting Spacing

The interaction between nitrogen level and planting spacing was found to be non-significant with respect to the number of leaves per plant.

Table 3.2: Effect of nitrogen level and planting spacing on number of leaves per plant

Treatment	20 DAT	40 DAT	At harvest
Nitrogen Level			
N_1	9.76	13.84	14.16
N_2	9.78	14.33	14.70
N_3	9.40	13.36	13.82
SE ±	0.24	0.61	0.58
C. D. at 5%	NS	NS	NS
Planting Spacing (cm)			
S_1	9.84	13.91	14.28
S_2	9.87	14.07	14.48
S_3	9.22	13.56	13.92
SE ±	0.24	0.61	0.58
C. D. at 5%	NS	NS	NS
Interaction(NxP)			
SE(m)±	0.43	1.07	1.01
CDat5%	NS	NS	NS
General mean	7.74	13.35	12.26

4.1.3 Effect of Nitrogen Levels and Planting Spacing on Leaf Area (cm²) per Plant

Data on leaf area (cm²) per plant, recorded at various crop growth stages, are presented in Table 3.3.

4.1.3.1 Effect of Nitrogen

The effect of nitrogen application was found to be non-significant across all nitrogen levels: N_1 (100 kg N ha^{-1}), N_2 (125 kg N ha^{-1}), and N_3 (150 kg N ha^{-1}), with no notable differences in leaf area per plant.

4.1.3.2 Effect of Planting Spacing

Planting spacing had no significant effect on leaf area per plant at any spacing level: S_1 (30 × 15 cm), S_2 (30 × 30 cm), and S_3 (45 × 30 cm).

4.1.3.3 Combined Effect of Nitrogen Level and Planting Spacing: The interaction between nitrogen levels and planting spacing showed no significant influence on leaf area per plant.

Table 3.3: Effect of nitrogen level and planting spacing on leaf area (cm^2) per plant

Treatment	20 DAT	40 DAT	At harvest
Nitrogen Level			
N_1	141.67	286.84	287.36
N_2	146.18	288.56	289.14
N_3	137.10	273.86	274.40
SE ±	8.59	34.95	34.94
C. D. at 5%	NS	NS	NS
Planting Spacing (cm)			
S_1	132.39	283.64	284.13
S_2	162.30	312.11	312.71
S_3	130.26	253.50	254.06
SE ±	8.59	34.95	34.94
C. D. at 5%	NS	NS	NS
Interaction(NxP)			
SE(m)±	14.89	60.54	60.52
CDat5%	NS	NS	NS
General mean	17.57	37.04	36.96

4.1.3 Effect of nitrogen level and planting spacing on fresh weight of leaves per plant^{-1} (g)
Data on the fresh weight of leaves per plant were recorded in Table 3.4.

4.1.3.1 Effect of Nitrogen
The effect of nitrogen at N_2 (125 kg N ha^{-1}) was found to be significantly higher at harvest, with a fresh leaf weight of 23.51 g, compared to the other treatments. It was statistically similar at harvest to N_1 (100 kg N ha^{-1}), which recorded 16.40 g. In contrast, the minimum fresh leaf weight per plant (11.24 g) was observed under the N_3 (150 kg N ha^{-1}) treatment.

4.1.3.2 Effect of Planting Spacing
Planting spacing showed a significant effect on fresh leaf weight per plant across all levels: S_1 (30 × 15 cm), S_2 (30 × 30 cm), and S_3 (45 × 30 cm).

4.1.3.3 Combined Effect of Nitrogen Level and Planting Spacing
The combined effect of nitrogen level and planting spacing on fresh leaf weight per plant was found to be significant.

Table 3.4: Effect of nitrogen level and planting spacingon fresh weight of leaves per plant^{-1} (g)

Treatment	At harvest
Nitrogen Level	
N_1	16.40
N_2	23.51
N_3	11.24
SE ±	2.704
C. D. at 5%	S
Planting Spacing (cm)	
S_1	14.38
S_2	25.31
S_3	11.47
SE ±	2.704
C. D. at 5%	S
Interaction(NxP)	
SE(m)±	4.68
CDat5%	S
General mean	17.05

4.2 Yield Characters
4.2.1 Effect of nitrogen level and planting spacing on yield per plant (g)
The data on yield per plant as influenced by various treatments are presented in Table 3.5.

4.2.1.1 Effect of Nitrogen
The effect of nitrogen on yield per plant was found to be non-significant across all nitrogen levels: N_1 (100 kg N ha^{-1}), N_2 (125 kg N ha^{-1}), and N_3 (150 kg N ha^{-1}).

3.2.1.2 Effect of Planting Spacing
Planting spacing had a significant effect on yield per plant at all spacing levels: S_1 (30 × 15 cm), S_2 (30 × 30 cm), and S_3 (45 × 30 cm).

4.2.1.3 Combined Effect of Nitrogen Level and Planting Spacing
The combined effect of nitrogen level and planting spacing on yield per plant was found to be non-significant.

Table 3.5: Effect of nitrogen level and planting spacing on yield per plant (g)

Treatment	Yield per plant (g)
Nitrogen Level	
N_1	286.89
N_2	288.82
N_3	275.93
SE ±	8.209
C. D. at 5%	NS
Planting Spacing (cm)	
S_1	292.29
S_2	293.58
S_3	265.78
SE ±	8.209
C. D. at 5%	**S**
Interaction(NxP)	
SE(m)±	14.22
CDat5%	NS
General mean	283.88

4.2.2 Effect of nitrogen and planting spacing on yield per plot (kg)
The data on yield per plot as influenced by various treatments are presented in Table 3.6.

4.2.2.1 Effect of Nitrogen
The effect of nitrogen on yield per plot was found to be non-significant across all nitrogen levels: N_1 (100 kg N ha^{-1}), N_2

(125 kg N ha^{-1}), and N_3 (150 kg N ha^{-1}). However, nitrogen played a beneficial role in cell division and elongation.

4.2.2.2 Effect of Planting Spacing

Planting spacing had a significant effect on yield per plot. The spacing S_2 (30 × 30 cm) produced the highest yield at harvest, with 5.09 kg per plot, which was statistically similar to S_1 (30 × 15 cm), yielding 4.86 kg per plot. The lowest yield (4.55 kg per plot) was observed at S_3 (45 × 30 cm).

4.2.2.3 Combined Effect of Nitrogen Level and Planting Spacing

The combined effect of nitrogen level and planting spacing on yield per plot was found to be non-significant.

Table 3.6: Effect of nitrogen level and planting spacing on yield per plot (kg)

Treatment	Yield per plot (kg)
Nitrogen Level	
N_1	4.85
N_2	4.95
N_3	4.71
SE ±	0.108
C. D. at 5%	NS
Planting Spacing (cm)	
S_1	4.86
S_2	5.09
S_3	4.55
SE ±	0.108
C. D. at 5%	S
Interaction (NxP)	
SE(m)±	0.19
CDat5%	NS
General mean	4.83

4.2.3 Effect of nitrogen and planting spacing on gross yield (q/ha)

The data on gross yield as influenced by various treatments are presented in Table 3.7.

3.2.3.1 Effect of Nitrogen

The effect of nitrogen on gross yield (q/ha) was found to be non-significant across all nitrogen levels: N_1 (100 kg N ha^{-1}), N_2 (125 kg N ha^{-1}), and N_3 (150 kg N ha^{-1}).

3.2.3.2 Effect of Planting Spacing: Planting spacing had a significant effect on gross yield. The spacing S_2 (30 × 30 cm) produced the highest gross yield at harvest, with 84.27 q/ha, which was statistically similar to S_1 (30 × 15 cm), yielding 80.96 q/ha. The lowest gross yield (75.89 q/ha) was recorded at S_3 (45 × 30 cm).

3.2.3.3 Combined Effect of Nitrogen and Planting Spacing: The combined effect of nitrogen and planting spacing on gross yield (q/ha) was found to be non-significant.

Table 3.7: Effect of nitrogen level and planting spacing on gross yield (q/ha)

Treatment	Gross yield (q/ha)
Nitrogen Level	
N_1	80.76
N_2	81.92
N_3	78.43
SE ±	1.70
C. D. at 5%	NS
Planting Spacing (cm)	
S_1	80.96
S_2	84.27
S_3	75.89
SE ±	1.70
C. D. at 5%	S
Interaction(NxP)	
SE(m)±	2.94
CDat5%	NS
Generalmean	80.37

4.2.4 Effect of nitrogen and planting spacing on marketable yield (q/ha): The data on marketable yield as influenced by various treatments are presented in Table 3.8.

4.2.4.1 Effect of nitrogen: The effect of nitrogen were found non-significant for all the levels of nitrogen: N1 (100 kg N/ha^{-1}), N2 (125 kg N/ha^{-1}) and N3 (150 kg N/ha^{-1}) for marketable yield (q/ha).

4.2.4.2 Effect of planting spacing

The effect of planting spacing at S2 (30 x 30 cm) were found significant at the time of harvest (83.74 q/ha) over the rest of the treatments, and it was at par at the time of harvest (80.36 q/ha) with S1 (30 x 15 cm) of lettuce for the character of marketable yield. The minimum marketable yield (75.31 q/ha) was recorded from the S3 level (45 x 30 cm) treatment.

4.2.4.3 Combined effect of nitrogen and planting spacing

The combined effect of nitrogen and planting spacing were found non-significant for marketable yield (q/ha).

Table 3.8: Effect of nitrogen level and planting spacing on marketable yield (q/ha)

Treatment	Marketable yield (q/ha)
Nitrogen Level	
N_1	80.17
N_2	81.61
N_3	77.63
SE ±	1.723
C. D. at 5%	NS
Planting Spacing (cm)	
S_1	80.36
S_2	83.74
S_3	75.31
SE ±	1.723
C. D. at 5%	S
Interaction(NxP)	
SE(m)±	2.98
CDat5%	NS
General mean	79.80

4.3 Quality Characters

4.3.1 Effect of nitrogen and planting spacing on dry matter content (%)

The data on dry matter content as influenced by various treatments are presented in Table 3.9

4.3.1.1 Effect of Nitrogen

The effect of nitrogen at N_2 (125 kg N ha^{-1}) was found to be significant at harvest, producing the highest dry matter content of 2.93%, which was statistically similar to N_1 (100 kg N ha^{-1}) with 2.81% dry matter content. The lowest dry matter content (2.73%) was recorded under the N_3 (150 kg N ha^{-1}) treatment.

4.3.1.2 Effect of Planting Spacing

Planting spacing had a significant effect on dry matter content at all spacing levels: S_1 (30 × 15 cm), S_2 (30 × 30 cm), and S_3 (45 × 30 cm).

4.3.1.3 Combined Effect of Nitrogen and Planting Spacing

The combined effect of nitrogen and planting spacing on dry matter content in lettuce was found to be non-significant

Table 3.9: Effect of nitrogen level and planting spacing on dry matter content (%)

Treatment	Dry matterr content (%)
Nitrogen Level	
N_1	2.81
N_2	2.93
N_3	2.73
SE ±	0.046
C. D. at 5%	S
Planting Spacing (cm)	
S_1	2.79
S_2	2.89
S_3	2.78
SE ±	0.046
C. D. at 5%	NS
Interaction(NxP)	
SE(m)±	0.08
CDat5%	NS
General mean	2.82

4.3.2 Effect of nitrogen and planting spacing on chlorophyll content (mg/100 g)

The data on chlorophyll content as influenced by various treatments are presented in Table 3.10.

4.3.2.1 Effect of Nitrogen

The effect of nitrogen at N_2 (125 kg N ha^{-1}) was found to be significant at harvest, with a chlorophyll content of 45.38 mg/100 g, which was statistically similar to N_1 (100 kg N ha^{-1}) that recorded 44.48 mg/100 g. The lowest chlorophyll content (44.44 mg/100 g) was observed under N_3 (150 kg N ha^{-1}). The increase in chlorophyll content with nitrogen application is attributed to nitrogen being an essential component of chlorophyll and its critical role in the photosynthesis process. Similar findings were reported by Bassyouni (2016) in lettuce and Nemadozi *et al.* (2017) in baby spinach [34, 35, 36].

4.3.2.2 Effect of Planting Spacing: Planting spacing had a significant effect on chlorophyll content across all levels: S_1 (30 × 15 cm), S_2 (30 × 30 cm), and S_3 (45 × 30 cm).

4.3.2.3 Combined Effect of Nitrogen and Planting Spacing

The combined effect of nitrogen and planting spacing on chlorophyll content in lettuce was found to be non-significant.

Table 3.10: Effect of nitrogen level and planting spacing on chlorophyll content (mg/100 g)

Treatment	Chlorophyll content (mg/100g)
Nitrogen Level	**SPAD (Values)**
N_1	44.48
N_2	45.38
N_3	44.44
SE ±	0.036
C. D. at 5%	S
Planting Spacing (cm)	
S_1	44.51
S_2	45.40
S_3	44.39
SE ±	0.036
C. D. at 5%	S
Interaction (NxP)	
SE(m)±	0.06
CDat5%	NS
General mean	44.77

5. Conclusion

Based on the present investigation, it can be concluded that the application of nitrogen and appropriate planting spacing plays a crucial role in enhancing the growth, yield, and quality of lettuce. The application of nitrogen at 125 kg N ha⁻¹ significantly improved growth parameters, such as plant height (19.02 cm), number of leaves per plant (14.70), leaf area (289.14 cm²), and fresh weight of leaves per plant (23.51 g). Yield attributes also showed marked improvement, including yield per plant (288.82 g), yield per plot (4.95 kg), gross yield (81.92 q/ha), and marketable yield (81.61 q/ha). Additionally, quality traits such as dry matter content (2.93%), fibre content (2.23%), and chlorophyll content (45.38 mg/g) were enhanced.

Similarly, a planting spacing of 30 × 30 cm resulted in better growth performance, with plant height (19.18 cm), number of leaves per plant (14.48), leaf area (312.71 cm²), and fresh leaf weight per plant (25.31 g). This spacing also contributed to higher yields yield per plant (293.58 g), yield per plot (5.09 kg), gross yield (84.27 q/ha), and marketable yield (83.74 q/ha). Quality traits including dry matter content (2.89%), fibre content (2.19%), and chlorophyll content (45.40 mg/g) were also positively influenced.

Therefore, under Marathwada conditions, the combined application of 125 kg N ha⁻¹ and a planting spacing of 30 × 30 cm per hectare is recommended for optimal lettuce cultivation.

References

1. Abdelraouf EA. The effects of nitrogen fertilization on yield and quality of spinach grown in high tunnels. Alexandria Science Exchange Journal. 2016;37(July-September):488-496.
2. Afroz R, Hanaki K, Hasegawa-Kurisu K. Willingness to pay for waste management improvement in Dhaka city, Bangladesh. Journal of Environmental Management. 2009;90(1):492-503.
3. Armstrong RG, Hollingsworth JW, Campbell E. Caffeine as a repellent for slugs and snails. Nature. 2002;417(6892):915-916.
4. Basel N, Rosen CJ, Fritz VA. Nitrate content in lettuce (*Lactuca sativa* L.) heads in relation to plant spacing, nitrogen form and irrigation level. Journal of the Science of Food and Agriculture. 2004;84(9):931-936.
5. Bhangre KK, Sonawane PC, Warade SD. Effect of different varieties and spacing on growth and yield parameters of broccoli (*Brassica oleracea* var. *Italica Plenck* L.) under Pune conditions. Asian Journal of Horticulture. 2011;6(1):74-76.
6. Boukema IW, Hazekamp Th, van Hintum Th JL. The CGN lettuce collection. Centre for Genetic Resources, Wageningen. 1990;27.
7. Moraa C, Wachira P, Ndirangu S. Effect of nitrogen source, crop maturity stage and storage conditions on phenolics and oxalate contents in vegetable amaranth (*Amaranthus hypochondriacus*). Agricultural Science Journal. 2012;4(7).
8. Darshan SN, Vijaykumar NM, Gouraj V, Vinay GC, Murthy CM. Effect of varying levels of nitrogen on growth and yield of spinach (*Spinacia oleracea*). Journal of Emerging Technologies and Innovative Research. 2019;6(6):1-5.
9. El-Sayed SM. Use of spinach powder as functional ingredient in the manufacture of UF-soft cheese. Heliyon. 2020;6(1):e03184.
10. Khan F, Khan F, Jan MT, Khan N. Vegetative growth of cabbage in relation to sowing time, plant spacing and NPK grown under different localities of Azad Kashmir and Gilgit-Baltistan. 2015;24-27.
11. Gashaw B, Haile S. Effect of different rates of N and intrarow spacing on growth performance of lettuce (*Lactuca sativa* L.) in Gurage zone, Ethiopia. Advances in Agriculture. 2020;2020:1-8.
12. Glenn EP, Cardran P, Thompson TL. Seasonal effects of shading on growth of greenhouse lettuce and spinach. Scientia Horticulturae. 1984;24(3-4):231-239.
13. Hasan MR, Tahsin AKMM, Islam MN, Ali MA, Uddain J. Growth and yield of lettuce (*Lactuca sativa* L.) influenced by nitrogen fertilizer and plant spacing. IOSR Journal of Agriculture and Veterinary Science. 2017;10(6):62-71.
14. Helaly MA. Effect of nitrogen fertilization rates and potassium sources on broccoli yield, quality and storability. Research Journal of Agriculture and Biological Sciences. 2012;8(4):385-394.
15. Hussain MF, Ara N, Uddin MR, Dey S, Islam MR. Effect of time of sowing and plant spacing on broccoli production. Tropical Agricultural Research and Extension. 2011;14(4):90-92.
16. Hossain M, Islam R, Rahman A, Islam S. Effect of sowing date and plant spacing on seed production of

cauliflower. Journal of Agricultural Research in Bangladesh. 2015;40(3):491-500.

17. Ishaque K, Iqbal M, Jilani MS, Waseem K. Effect of nitrogen levels on lettuce growth and yield. Journal of Agricultural Research. 2009;47(4):1-5.
18. Islam R, Khatan K, Mostarin T, Haq E, Islam N, Biswas BR, Afsun J. Effect of nitrogen and phosphorus on the growth and seed yield of spinach. Asian Plant Research Journal. 2019;3(1):1-9.
19. Jackson M, Gallardo LE, Thompson RB. Shoot and root physiological responses to localized zones of soil moisture in cultivated and wild lettuce (*Lactuca* spp.). Plant, Cell & Environment. 1996;19(10):1169-1178.
20. Jangu R, Yadav R, Kumari S, Sharma P, Kumawat P. Determining the combined effect of nitrogen and spacing on growth parameters in lettuce (*Lactuca sativa* L.). The Pharma Innovation Journal. 2022;11(2):1740-1745.
21. Kallo IM. Influence of nitrogen and phosphorus on growth and yield of lettuce (*Lactuca sativa* L.) [dissertation]. Department of Horticulture; 2008.
22. Katiyar D, Tripathi SM, Dwivedi AK, Pandey V. Effect of nitrogen and phosphorus on crop growth, head yield and quality of broccoli (*Brassica oleracea* L. *italica*). HortFlora Research Spectrum. 2012;1(2):172-174.
23. Kavalgi AR, Rajyalakshmi K, Jyothi U, Krishna KU. Studies on the effect of nitrogen levels on growth, yield components and quality of red cabbage (*Brassica oleracea* var. *capitata* f. *rubra*). International Journal of Current Microbiology and Applied Sciences. 2020;9(1):367-374.
24. Kim MJ, Moon Y, Tou JC, Mou B, Waterland NL. Nutritional value of crisphead 'Iceberg' and romaine lettuces (*Lactuca sativa* L.). Journal of Agricultural Science. 2016;8(11):201-216.
25. Kumar N, Prakash V, Srivastava AK. Effect of transplanting dates and geometries on broccoli (*Brassica oleracea* cv. *Italica*) under mid-hill conditions of north-west Himalaya. Indian Journal of Agricultural Science. 2007;77(7):448-450.
26. Ryder EJ. Lettuce breeding. In: Wien HC, editor. The Lettuce Crop. Boston (MA): Springer US; 1998. p. 305-342.
27. Deshpande SS, Salunkhe DK. Celery and other salad vegetables. In: Salunkhe DK, Kadam SS, editors. Handbook of Vegetable Science and Technology: Production, Composition, Storage, and Processing. Boca Raton (FL): CRC Press; 1998. p. 579-619.
28. Relf D, McDaniel A. Home Garden Vegetables: Leafy Greens [Internet]. Blacksburg (VA): Virginia Cooperative Extension; 2000 [cited 2025 Oct 15]. Report No.: 426-420. Available from: https://vtechworks.lib.vt.edu/handle/10919/48805
29. Wurr DCE, Phelps K, Fellows JR. The effect of transplant size and age on the growth and development of crisp lettuce. J Hortic Sci. 1992;67(1):129-136.
30. Wurr DCE, Fellows JR, Pittam AJ. The influence of plant raising conditions and transplant age on the growth and development of crisp lettuce. J Agric Sci. 1987;109(3):573-581.
31. Thompson TL, Langhans RW. Shoot and root temperature effects on lettuce growth in a floating hydroponic system. J Am Soc Hortic Sci. 1998;123(3):361-365.
32. Prasad B, Yadav NK, Choudhary BR. Effect of integrated nutrient management on growth, yield and quality of Chinese cabbage (Brassica rapa L. subsp. pekinensis). Hortic Flora. 2009;1(3):192-198.
33. Yadav A, Ali S, Ahmad T, Kumar K, Rizvi IA, Agarwal A, *et al.* Effect of projectile break-up threshold energy on incomplete fusion at energy ≈4-7 MeV/nucleon. Phys Rev C. 2012;86(1):014603.
34. Bassyouni SMS. Effect of growth seasons and nitrogen fertilization on the growth, yield and nitrate accumulation of lettuce (*Lactuca sativa* L.) plants. Egypt J Appl Sci. 2016;31(10):115-131.
35. Nemadodzi TM, Bairu MW, Masevhe SN, Mashilo J. The quality of baby spinach as affected by developmental stage as well as postharvest storage conditions. Acta Agric Scand B Soil Plant Sci. 2017;67(6):496-506.