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Effect of different level of nitrogen on different plant spacing on growth, yield and quality of kale

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Abstract
Many vegetables in the Brassicaceae family are being grown in Prayagraj (Allahabad), yet kale is not well-known and not much research is done on this crop in this region. Kale has a high nutritional and economic value, therefore if grown on large scale may help the farmers to procure a better and extra income compared to other well-known crops. A trial was conducted at the Vegetable Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology & Sciences, Prayagraj (UP) during 2023 to study the "Effect of different levels of Nitrogen and Plant Spacing on growth yield and quality of Kale (*Brassica oleracea var. acephala*)", with four different doses of nitrogen i.e.15 kg, 20 kg, 25 kg and 30 kg each arranges at two different plant spacings of 40 cmx25 cm and 50 cmx35 cm. The results revealed that maximum plant height, leaf area, number of leaves per plant, average head weight, yield per plot, yield per hectare, TSS and ascorbic acid content were found in T_8 (Nitrogen = 30 kg and spacing = 40 cm x 25 cm).

Keywords: Kale, plant spacing, nitrogen

1. Introduction
Kale, a staple in various global cuisines for centuries, has seen a surge in popularity, particularly the curly variety, due to its impressive nutritional profile and health benefits. Often referred to as the "king of leafy greens" and closely related to wild cabbage, kale was introduced in the 19th century as a minor temperate vegetable. While commercial cultivation in India remains limited, its popularity in the hotel industry is on the rise. Curly kale boasts high levels of vitamins A, C, and K, and minerals like calcium, potassium, and iron. It's also packed with antioxidants, including carotenoids and flavonoids, known for their anti-inflammatory and anti-cancer benefits. Moreover, kale's low-calorie and high-fibre content make it an excellent choice for weight management and supporting digestive health.

Green leafy vegetables occupy an important place among the food crops as they provide adequate amounts of many vitamins and minerals for humans. They are rich sources of carotene, ascorbic acid, riboflavin, folic acid and minerals like calcium, iron and phosphorus. The strategic interplay between plant geometry andnitrogen availability is pivotal in the growth and development of leafy vegetables. Plant geometry, which dictates the spatial arrangement of plants, ensures optimal light exposure and nutrient absorption, both of which are essential for photosynthesis and overall plant health. Nitrogen, a key component of chlorophyll, amino acids, and proteins, is fundamental for vegetative growth, particularly in leafy greens where the foliage is the primary edible part.

Plants primarily absorb nitrogen in the forms of NH4+ and NO3-. Regardless of the initial form, once absorbed by plant roots, nitrogen is converted into the reduced form NH_2 (amide). This then combines with carboxylic acid to form amino acids. These amino acids are fundamental for synthesizing proteins, which are crucial for building protoplasm. Thus, nitrogen is a vital element for all living matter. (Soeparno 1992) [11]. Adequate nitrogen enhances leaf expansion, chlorophyll concentration, and biomass production, leading to lush, nutritious vegetables.

A spatial arrangement of plant governs the shape and size of the leaf area per plant, which in turn influences efficient interception of radiant energy as well as proliferation and growth of roots and their activity.

Maximum yield can be expected only when plant population allows individual plant to achieve their maximum inherent potential. Thus, there is need to work out an optimum population density by adjusting inter and intra row spacing in relation to other agronomic factors. Together, the careful management of plant geometry and nitrogen fertilization can significantly boost the yield and quality of leafy vegetables, making them a powerhouse of nutrition in our diets**.**

2. Materials and Methods

2.1 Experimental details

The experiment was carried out at the Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, U.P., India. The study was conducted using a Randomized Block Design with one variety and eight different treatments across three replications. Each treatment involved a combination of a nitrogen dose in the form of urea and a specific plant geometry. Treatments were allocated to individual plots using random numbers in each replication.

2.2 Climatic conditions

Prayagraj is situated at an elevation of 78 meters above sea level at 25.87degree North latitude and 81.15degree E longitude. This region has a sub-tropical climate prevailing in the south- east part of U.P. with both the extremes in temperature, i.e the winter and the summer. In cold winters, the temperature sometimes is as low as 32°F in December – January and very hot summer with temperature reaching up to 115°F in the months of May and June. During winter, frosts and during summer, hot scorching winds are very common. The average monthly rainfall, relative humidity, minimum and maximum temperature were recorded during the experimental period**.**

Statistical Analysis

Except where otherwise noted, all data were presented as means ± standard errors (SE) of three replications, and one-way analysis of variance (ANOVA) was performed using Duncan's test at $p< 0.05$ by STATISTICA (7.0) software (Informer TechnologiesInc., 6800 Altamor Drive, Los Angeles, USA).

Table 1: Details of Treatment Combination

Sr. No	Treatment	Treatment Combination N(kg), S(cm)
1	T_1	Control plot, RDF
2	T_2	N=15 kg and S = 40 cm x 25 cm
3	T_3	N=15 kg and S = 50 cm x 35 cm
4	T_4	N=20 kg and S = 40 cm x 25 cm
5	T_5	N=20 kg and S = 50 cm x 35 cm
6	T_6	N=25 kg and S = 40 cm x 25 cm
7	T_7	N=25 kg and S = 50 cm x 35 cm
8	T_8	N=30 kg and S = 40 cm x 25 cm
9	T_9	N=30 kg and S = 50 cm x 35 cm

N – Nitrogen, S– Spacing, RDF— Recommended Dose of Fertilizer (N:P:K=200 kg,125 kg 150 kg)

3. Results and Discussion

3.1 Growth parameters

3.11 Plant Height

Growth parameters for Kale, such as days to germination, plant height (cm), and plant spread at 30, 60, and 90 days after sowing, as well as at harvest, are detailed in Table 2. The longest germination time was observed in crops treated with T_6 (N=25 kg and S=40 cm x 25 cm) and T_8 (N=30 kg and S=40 cm x 25 cm), taking 9.36 days, while the shortest was in T_9 (N=30 kg and S=50 cm x 35 cm). Maximum plant height was reported (Nitrogen=30 kg and Spacing= 40 cm x 25 cm) (T_8) with an average height of 40.07 cm followed by (Nitrogen =30 kg and Plant Spacing= 50 cm x 35 cm) (T_9) with an average height recorded 39.47 cm which was significantly higher from rest of treatments. All the treatments have shown a significant increase in plant height as compared to control plot (T_1) which was only 30.33 cm.

The increase in plant height could be due to the ability of microbial inoculants to produce some growth promoting substances, nitrogen fixing along which might have led to enhanced cell division and cell elongation, resulting in better root development, increased uptake of nutrients and moisture (Kamili *et al*., 2002) [5].

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Table 2: The impact of varying nitrogen doses on germination time and height of kale

Plot No	Treatment Combination N= kg S= cm	Days to Germination	Plant Height (cm)			
			30 DAS	60DAS	90DAS	At Harvest
T_1	Control, RDF	9.35	10.60	20.47	30.33	30.33
T_2	N=15 kg and S= 40 cm x 25 cm	9.33	12.67	21.67	31.53	31.53
T_3	N=15 kg and S=50 cm x 35 cm	9.34	13.27	22.73	32.73	32.73
T_4	N=20 kg and S=40 cm x 25 cm	9.34	15.87	24.20	34.80	34.80
T_5	N=20 kg and S=50 cm x 35 cm	7.98	17.40	26.20	36.53	36.53
T_6	N=25 kg and S=40 cm x 25 cm	9.36	19.67	28.87	38.27	38.27
T_7	N=25 kg and S=50 cm x 35 cm	9.32	21.33	30.07	39.07	39.07
T_8	N=30 kg and S=40 cm x 25 cm	9.36	22.00	31.07	40.07	40.07

T_9	N=30 kg and S=50 cm x 35 cm	7.65	21.73	30.07	39.47	39.47
F-Test		S	S	S	S	S
S. Ed. ±		0.24	1.14	1.81	1.51	1.51
CD at 5%		0.50	2.43	3.83	3.21	3.21
CV		3.21	8.16	8.46	5.16	5.16

Maximum, Minimum

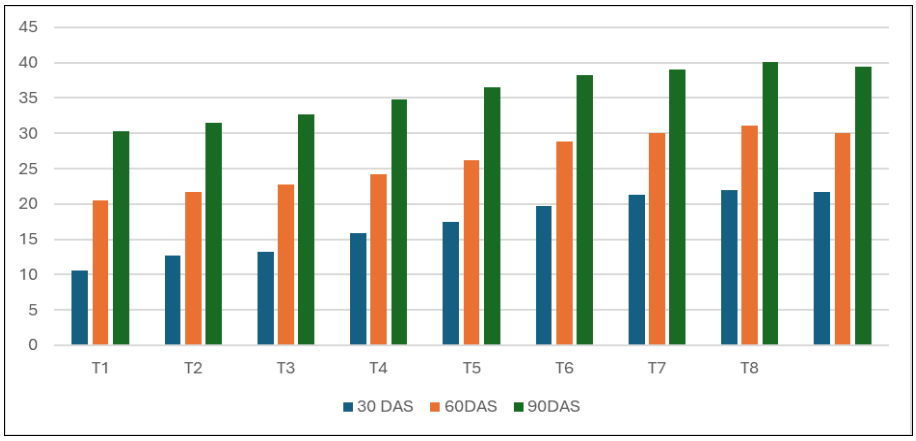

Chart 1: Observed plant height at respective days in kale

Description: The table and graph show maximum germination at N=20 kg and S=50 cm x 35 cm (T_6) with 9.36, and at N=30 kg and S=40 cm x 25 cm (T_8) also with 9.36. The minimum germination is observed at N=30 kg and S=50 cm x 35 cm (T_9) with 7.65. Maximum plant height at 30DAT, 60DAT, 90DAT, and at harvest was recorded as 22.00 cm, 31.07 cm, 40.07 cm, and 40.07 cm, respectively, at N=30 kg and S=40 cm x 25 cm (T_8). Minimum plant height at 30DAT, 60DAT, 90DAT, and at harvest was 10.60 cm, 20.47 cm, 30.33 cm, and 30.33 cm, respectively, in T_1 (Control).

The increase in plant height could be due to the ability of microbial inoculants to produce some growth promoting substances, nitrogen fixing along which might have led to enhanced cell division and cell elongation, resulting in better root development, increased uptake of nutrients and moisture (Kamili *et al*., 2002) [5].

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3.12 Survival percentage and Days to Head colouring

Kale colouring was measured in terms of days. The maximum days to colouring were observed in treatment T_3 (Nitrogen = 15 kg and Spacing = 50 cm x 35 cm), with an average of 38 days, followed by treatment T_1(control RDF), with an average of 37.33 days, which was significantly higher than the rest of the treatments. All treatments showed a significant increase in days to colouring compared to T_8, which had the minimum average of 32.67 days. This data leads us to conclude that the dose of nitrogen and optimal plant spacing have a significant impact on the colouring process in kale.The highest survival rate (100%) was recorded in T_2, T_5, and T_8, whereas the lowest was noted in T_7, at 97.67% (as seen in table 3). A high survival percentage is often attributed to ideal weather conditions, adequate soil moisture, appropriate nitrogen application, and correct plant spacing.

Table 3: Survival Percentage and Days to colouring of Head

Plot No.	Treatment combination N (kg), S (cm)	Survival Percentage	Days to Colouring
T_1	Control, RDF	98	37.33
T_2	N=15 kg and S= 40 cm x 25 cm	100	36.33
T_3	N=15 kg and S=50 cm x 35 cm	98.33	38
T_4	N=20 kg and S=40 cm x 25 cm	99	35
T_5	N=20 kg and S=50 cm x 35 cm	100	34
T_6	N=25 kg and S=40 cm x 25 cm	98.67	33.67
T_7	N=25 kg and S=50 cm x 35 cm	97.67	36.67
T_8	N=30 kg and S=40 cm x 25 cm	100	32.67
T_9	N=30 kg and S=50 cm x 35 cm	98.67	36
F-Test		S	S
S. Ed. ±		0.51	0.80
CD at 5%		1.07	1.69
CV		0.63	2.75

Description: The table shows that the highest survival percentages are observed in T_2, T_5, and T_8, while the lowest is in T_7. The maximum number of days to colouring is recorded in T_9 (N=30 kg and S=50 cm x 35 cm), which is 37.33 days, and the minimum is in T_8 (N=30 kg and S=40 cm x 25 cm), being 32.67 days.

3.13 Leaf Area and No. of leaves: As shown in the table 5, the leaf area of 96.32 cm^2 was recorded with the (Nitrogen=30 kg and Spacing = 40 cm x 25 cm) (T_8) application which was significantly higher as compared to rest of treatments. Minimum value of leaf area index 86.03 cm^2 was reported (T_1) which was significantly lower from rest of treatments. Wide spacing increased mean fresh weight, branching and leaf production of kale plants. Close spacing significantly increased total leaf yield per hectare, but decreased leaf:petiole ratio per plant**.** (Chweya, J.A. (1984) [13].

In the year 2019, Qi *et al*. evaluated that optimal combinations of nitrogen and potassium fertilizers led to increased plant height, leaf size, and chlorophyll content in kale plants. High nitrogen supply combined with potassium application resulted in higher leaf yield, total biomass, and enhanced photosynthetic activity.

Table 5: Effect of Nitrogen on Number of leaves and leaf area

Plot No.	Treatment Combination	No. of Leaves			Leaf area (cm^2)
		30 DAS	60 DAS	90 DAS	
T_1	Control, RDF	6.00	12.00	18.00	86.03
T_2	N=15 kg and S= 40 cm x 25 cm	7.00	13.67	19.00	94.03
T_3	N=15 kg and S=50 cm x 35 cm	8.00	14.33	20.00	86.58
T_4	N=20 kg and S=40 cm x 25 cm	10.00	15.67	21.00	90.67
T_5	N=20 kg and S=50 cm x 35 cm	12.67	17.00	23.33	90.15
T_6	N=25 kg and S=40 cm x 25 cm	14.33	19.67	25.00	87.11
T_7	N=25 kg and S=50 cm x 35 cm	16.00	21.00	27.00	91.75
T_8	N=30 kg and S=40 cm x 25 cm	17.00	22.00	28.00	96.32
T_9	N=30 kg and S=50 cm x 35 cm	16.00	21.00	27.00	86.37
F-Test		S	S	S	S
S. Ed. ±		1.06	1.07	1.12	1.77
CD at 5%		2.25	2.28	3.64	3.76
CV		10.95	7.58	9.09	2.41

Maximum, Minimum

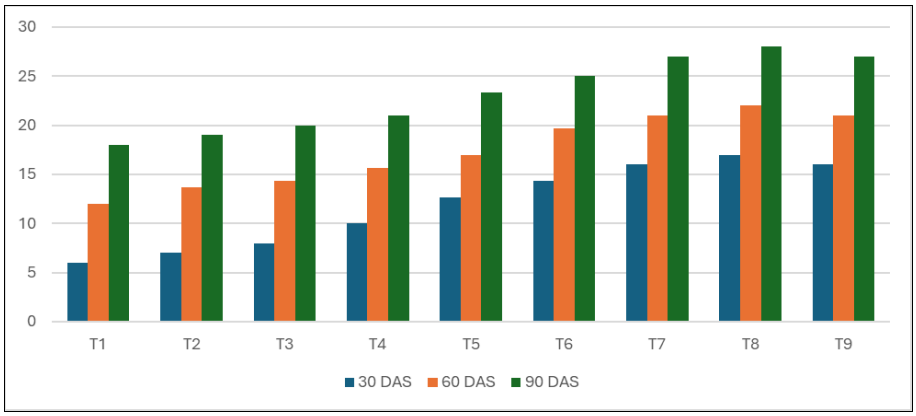

Chart 2: No. of leaves in kale at respective days

Description: The table and chart show that the maximum leaf count was observed after 30, 60, and 90 days in the treatment with 30 kg of nitrogen and a spacing of 40 cm x 25 cm (T_8), with counts of 17.00, 22.00, and 28.00 respectively. The minimum leaf count was recorded in the control treatment (T_1) with RDF, showing 6, 12, and 18 leaves. The largest leaf area was found in T_8 (N=30 kg and S=40 cm x 25 cm), measuring 96.32 cm^2, while the smallest was in the control treatment (T_1) with RDF, measuring 86.03 cm^2.

3.14 Head weight and Yield per plot

Table 6 presents observations on Head Weight (g) and head yield per plot (kg). The maximum Head Weight was recorded at 686.99 g for the treatment with 30 kg Nitrogen and 40 cm x 25 cm spacing (T_8), while the control treatment had the minimum weight of 637.47 g. The highest number of leaves per plant was 22.33, also in treatment T_8, and the lowest was 12 in the control treatment, which was significantly lower. The largest Head Diameter observed was 40.20 cm in treatment T_8.

Maximum Head yield per plot i.e., 6.18 kg was obtained in (Nitrogen=30 kg and Spacing = 40 cm x 25 cm)in T_8 which was significantly higher from rest of the treatments followed by (Nitrogen=30 kg and Spacing = 50 cm x 35 cm) in T_9 i.e. 6.16 kg and (Nitrogen=25 kg and Spacing 50 cm x 35 cm) in T_7 i.e. 6.16 kg. The minimum Head yield per plot i.e., 6.06 kg recorded from the plot which was kept control (T_1) and it was significantly lower from rest of treatments. The data showed that maximum yield of 30.90(tons/ha) with the treatment (T_8) was reported using different level of Nitrogen on different plant spacing were followed by treatment(T_9) with the value of 30.76 (tons/ha). Minimum yield of kale was recorded in weedy check (T_1) 28.68 (tons/ha) which was significantly lower from rest of treatments conducted a study on the impact of varying spacing and nitrogen levels on cauliflower growth and yield. The research aimed to assess several parameters, including survival percentage, days to curd initiation from transplanting, number of leaves per plant, plant height (cm), curd diameter (cm), average curd weight (g), and total curd weight (kg/ha). The findings indicated that nitrogen (80 kg/ha) and plant spacing (55 cm) significantly influenced all measured parameters. His research findings are very similar to ours.

Table 6: Effect of Nitrogen on Head Weight and Head Yield per plot

Plot No.	Treatment Combination	Head weight in gram	Head yield/plot(kg)
T_1	Control, (RDF)	637.47	6.10
T_2	N=15 kg and S= 40 cm x 25 cm	671.59	6.20
T_3	N=15 kg and S=50 cm x 35 cm	673.40	6.30
T_4	N=20 kg and S=40 cm x 25 cm	678.18	6.40
T_5	N=20 kg and S=50 cm x 35 cm	679.47	6.50
T_6	N=25 kg and S=40 cm x 25 cm	680.82	6.60
T_7	N=25 kg and S=50 cm x 35 cm	683.40	6.70
T_8	N=30 kg and S=40 cm x 25 cm	686.99	6.80
T_9	N=30 kg and S=50 cm x 35 cm	683.70	6.60
F-Test		S	S
S. Ed. ±		6.80	0.30
CD at 5%		14.42	0.14
CV		19.87	2.68

Maximum, Minimum

Description: After 90 days maximum weight are found in N=30 kg and S=40 cm x 25 cm T_8 i.e. 686.99g and minimum weight are found in T_1control (RDF) i.e. 637.47.Maximum Head yield/plot are found in N=30 kg and S=40 cm x 25 cm T_8 i.e. 6.18.Minimum Head yield/plot are found in T_1control (RDF) i.e. 6.06 kg

3.2Phytochemical contents

3.21 Ascorbic acid and Total Soluble Solid (TSS)

Among the treatments, the application of Nitrogen at 30 kg and Spacing at 40 cm x 25 cm (T_8) resulted in the highest increase in ascorbic acid content, reaching 16.42 mg/100g, followed by treatment T_9 with 15.84 mg/100g. Treatment T_8 also achieved the highest Total Soluble Solids (TSS) at 0°Brix, significantly surpassing the control treatment T_1 and others. The maximum TSS value in kale was observed in T_8 at 124.93 0°Brix, while the minimum was in T_1 (Control) at 93.10 0°Brix, as indicated in table 7 investigated the effects of different nitrogen sources (ammonium nitrate, urea, and ammonium sulphate) on nutrient uptake and TSS in curly kale. The findings revealed that the application of ammonium nitrate resulted in the highest TSS levels when compared to other nitrogen sources and also showed a positive correlation between nitrogen uptake and TSS.

Table 7: Effect of Nitrogen on Ascorbic Acid(mg/100gm) and TSS(°Brix)

Sr. No	Treatment Combination	Ascorbic Acid(mg/100g)	TSS (°Brix)
T_1	Control, RDF	93.11	10.99
T_2	N=15 kg and S= 40 cm x 25 cm	97.65	11.61
T_3	N=15 kg and S=50 cm x 35 cm	102.13	13.18
T_4	N=20 kg and S=40 cm x 25 cm	109.15	13.23
T_5	N=20 kg and S=50 cm x 35 cm	113.17	14.25
T_6	N=25 kg and S=40 cm x 25 cm	109.19	14.26
T_7	N=25 kg and S=50 cm x 35 cm	116.31	15.59
T_8	N=30 kg and S=40 cm x 25 cm	124.89	16.42
T_9	N=30 kg and S=50 cm x 35 cm	116.89	15.84
F-Test		S	S
S. Ed. ±		5.31	1.19
CD at 5%		11.26	2.53
CV		5.96	10.50

Maximum, Minimum

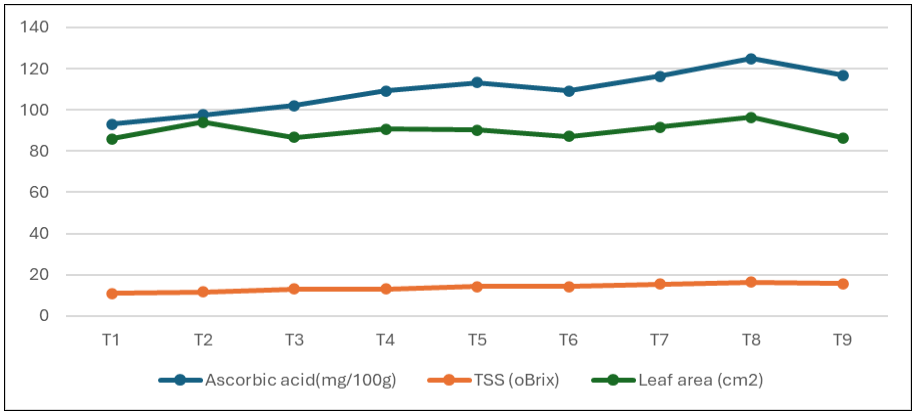

Chart 3: Leaf area, Ascorbic Acid and TSS value in Kale

Description

In this table, we note that the highest Ascorbic acid content is found in T_8 (N=30 kg S=40 cm x25 cm), which is 124.89 mg/100g, while the lowest is in the T_1 control (RDF) at 93.11 mg/100g. The maximum Total Soluble Solids (TSS) are observed in T_8 (N=30 kg S=40 cm x5 cm) at 16.42 °Brix and the

minimum TSS is in the T_1 control (RDF), at 10.99 ^{o}Brix. *The chart showsa changing trend in leaf area, amount of ascorbic acid and the Total Soluble Solid content in the leaves of kale at different growth periods.

Conclusion

The experiment "Effect of different levels of Nitrogen and Plant Spacing on growth yield and quality of Kale (Brassica oleracea var. acephala)"conducted during (Rabi) season of 2023-2024 at Vegetable Research Farm, Department of Horticulture, SHUATS, prayagraj showed best performance in treatmentT_8(N=30 kg and S=40 cmx25 cm) was found to be best in the terms of growth *viz*. plant height, Leaf area, days to germination, days to head pickling, number of leaves per plant, and in terms of yield *viz*. average leaves weight, leaf Yield per plot, head weight per plot, head diameterand in terms of quality *viz*. ascorbic acid content and TSS content of leaves.

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