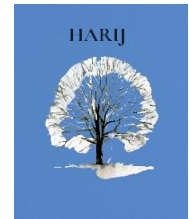




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Effect of Different level of Nitrogen on growth and Productivity of Spinach in Helmand Province

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Abstract: This study was conducted on a 100 m² area at Helmand University to investigate the effects of different nitrogen levels on the growth and yield of spinach (*Spinacia oleracea*). Spinach is known for its high nutritional value, being rich in fiber, vitamins, and minerals. Overall, the application of nitrogen had a positive effect on the growth and yield of spinach. The study aimed to evaluate plant height, number of leaves, leaf width, and yield in kilograms per hectare. Four treatments were applied with varying nitrogen levels (T1 - 120, T2 - 100, T3 - 80, and T4 - 0 kg/ha), assessed using a Randomized Complete Block Design (RCBD) with four replications. The highest plant height was recorded in T1 (120 kg N/ha), measuring 29.67 cm. The highest number of leaves was also found in T1, with an average of 18.77. Similarly, the widest leaves (10.15 cm) were recorded in T1. The yield was also highest in T1, with 15,575 kg/ha achieved using 120 kg N/ha.

Keywords: Spinach, Nitrogen, Growth, Yield.

1. Introduction

The scientific name of spinach is *Spinacia oleracea*, which belongs to the family *Amaranthaceae*. In English, it is called "spinach," a word derived from the Persian term *aspanākh*, meaning "green hand." Over time, it evolved into *spanchia* in Latin, and then into *spinach* in English. The origin of spinach is believed to be in southwestern Asia, and it was introduced to China via Nepal in the early 7th century. Globally, there are about 102 genera and over 1,400 species of spinach (Mortati, 2008). To understand its importance, it is worth noting that global spinach production currently reaches 27.88 million tons, with China contributing 23.8 million tons, the USA 384,669 tons, Japan 226,382 tons, and Turkey 250,174 tons. The average yield per hectare is about 10–15 tons (Mirjalili, 2021). Spinach is an annual, leafy green vegetable cultivated primarily in spring, autumn, and winter. It is consumed both cooked and raw. Fresh spinach contains approximately 91% water, 4% carbohydrates, 3% protein, and very little fat. It is low in calories and rich in nutritional content. Spinach contains high levels of vitamins such as A, B1, B2, and C, as well as minerals like calcium, iron, phosphorus, potassium, sodium, and magnesium. Its fiber content aids digestion (Abdelraouf, 2016). Besides its nutritional value, spinach also has medicinal properties. Due to its high calcium and vitamin K content, it strengthens bones. Its carotenoid compounds help maintain eye health, reduce vision deterioration, and are believed to be effective against dry cough and even cancer. Moreover, it supports the production of red blood cells. Spinach is among the fast-growing vegetables and requires a short growing period. It thrives in cool climates and can tolerate temperatures as low as 5–6°C. The optimum germination temperature is around 16°C. The plant can grow up to 30 cm in height and has leaves of varying shapes and sizes. Fertilizer application plays a crucial role in improving both the quantity and quality of spinach yield, especially nitrogen, which is an essential nutrient for plant growth. Nitrogen is vital for plant development as it contributes to amino acid synthesis and is a key component of chlorophyll, necessary for photosynthesis. It also influences cell division and the absorption of phosphorus and potassium. A deficiency in nitrogen can result in poor growth and yellowing of the leaves (Darshan et al., 2019).

In Afghanistan, spinach is cultivated widely and is an important crop in the vegetable sector. In Helmand province, although spinach is grown in various regions, the yield per unit area remains lower than in other regions. One of the possible reasons could be the improper application of nitrogen fertilizer. Overuse of nitrogen not only reduces food quality but also leads to economic loss, environmental degradation, and increased nitrate content in the plant, which can be harmful to both humans and animals (Canali et al., 2008). Spinach, being a fast-growing and nutrient-demanding plant,

needs proper fertilization, particularly nitrogen, to ensure a high-quality yield. Although nitrogen positively influences spinach growth and productivity (Darshan et al., 2019), there is limited data available on the appropriate nitrogen levels for spinach cultivation in Helmand province. Therefore, this study was conducted in the Lashkargah area, under the domain of Helmand University, to investigate the effect of nitrogen on spinach growth and yield.

Research Problem

Spinach is one of the major vegetables grown in various parts of Helmand province. However, the yield per unit area is lower than in other regions. This may be due to several factors, one of which is the improper use of nitrogen fertilizer. Overapplication can result in economic loss, environmental damage, and poor food quality. Additionally, excessive nitrogen increases nitrate concentration in spinach, which poses health risks to both humans and animals.

Significance of the Study

To achieve a high-quality yield, spinach requires appropriate nutrients—especially nitrogen. Nitrogen significantly impacts the growth, yield, and quality of spinach. This study aims to identify the optimal nitrogen level for spinach cultivation. The results will be beneficial for agricultural professionals and farmers, enabling them to apply the recommended amount of nitrogen in the field, improve yield, enhance farmers' income, and ultimately contribute to the national economy.

Objectives

- To evaluate the response of spinach to different levels of nitrogen fertilizer.
- To determine the optimal nitrogen level for spinach cultivation.
- To reduce nitrogen fertilizer waste.
- To prevent economic loss for farmers.
- To increase spinach yield per unit area.

2. Materials and Method

Study Area and Duration

This research was conducted in the vicinity of Helmand University, located in Lashkargah, the center of Helmand province. The study area has a hot and arid climate with an average annual rainfall of 121 mm, relative humidity ranging from 8% to 26%, and wind speeds between 5–16 km/h. Geographically, the area is situated at 31°34'47" N latitude and 64°22'09" E longitude, with an elevation of 798 meters above sea level. The soil of the experimental field is sandy loam in texture, with a pH of 7.5 and low organic matter content.

The experiment began on 21 Aqrab 1402 (November 12, 2023) and continued until 15 Dalwa 1402 (February 4, 2024). The study was conducted on spinach (*Spinacia oleracea*) using the 'Weresem' variety. The total area of the experimental field was **100 m²**. The experiment was carried out under the title: "*The Effect of Nitrogen on the Growth and Yield of Spinach in Helmand Province*", using a **Randomized Complete Block Design (RCBD)** in an open field. RCBD was chosen due to the difficulty of ensuring uniform conditions in the field. This design helps minimize the effects of uncontrolled factors such as soil fertility variations, wind direction, and potential diseases by arranging treatments in blocks.

There were **four nitrogen treatments**, each replicated **four times**, resulting in a total of **16 plots**. The size of each plot was **2.5 m × 2.5 m = 6.25 m²**.

Land Preparation and Sowing

Land preparation was completed on 15 Aqrab 1402 (November 6, 2023). Five days after land preparation, spinach seeds were sown on 21 Aqrab 1402 (November 12, 2023). The spacing between plants was maintained at 20 cm × 15 cm, resulting in 208 plants per plot.



Figure 1: Land Preparation and Sowing

Fertilizer Application

In this experiment, four nitrogen levels were applied: T1 – 120 kg/ha, T2 – 100 kg/ha, T3 – 80 kg/ha, and T4 – 0 kg/ha. Each nitrogen treatment was split into two equal doses:

- The first dose was applied before sowing using the broadcasting method:
 - T1 – 60 kg N/ha
 - T2 – 50 kg N/ha
 - T3 – 40 kg N/ha
 - T4 – 0 kg N/ha
- The second dose was applied 40 days after sowing, also by broadcasting:
 - T1 – 60 kg N/ha
 - T2 – 50 kg N/ha
 - T3 – 40 kg N/ha
 - T4 – 0 kg N/ha



Figure 2: Fertilizer Application

Irrigation

In this study, irrigation was carried out **10 times**. The schedule of irrigation is presented in the table below:

Table 1: Irrigation Schedule

Irrigation No.	Date (Hijri Solar)	Irrigation No.	Date (Hijri Solar)
1	1402/8/21	6	1402/10/01
2	1402/8/29	7	1402/10/09
3	1402/9/07	8	1402/10/17
4	1402/9/15	9	1402/10/25
5	1402/9/23	10	1402/11/03

Thinning and Weed Control

Thinning of the plants was performed on 1402/9/29. Weed control was conducted twice, on 1402/9/10 and 1402/10/10.



Figure 3: Thinning and Weed Control

Harvesting

Harvesting was carried out on 1402/11/15. After harvesting, **eight samples** were randomly collected from each plot to measure the number of leaves, leaf length, and leaf width. Additionally, the total yield from each plot was weighed to determine the yield quantity.



Figure 4: Thinning and Weed Control**Parameters Measured**

1. Number of leaves per plant
2. Leaf length (cm)
3. Leaf width (cm)
4. Yield (kg/ha)

Materials

In this study, primary data were directly collected from the experimental site. Secondary data were obtained from books, journals, scientific articles, and online websites. For data analysis, Microsoft Excel software was used.

Statistical Analysis

The recorded observations were statistically analyzed using Microsoft Excel based on the significance probability value. Results were considered significant at the 0.01 probability level. The discussion in this study is based on the 1% significance level. Wherever the differences between treatments were not significant, they are indicated as **NS** (not significant).

3. Results**Table 2: Leaf Number Plant⁻¹**

Treatments	R1	R2	R3	R4	TOTAL	AVERAGE
T1	18.1	19.1	17.9	18	73.1	18.275
T2	16.3	17.3	17.4	19	70	17.5
T3	15.3	16.3	16.4	15	63	15.75
T4 (check)	12.1	13.1	15.3	18	58.5	14.625

The highest number of leaves was observed in treatment T1, where 120 kg of nitrogen per hectare was applied, with an average of 18.7 leaves per plant. This difference was statistically significant at the 1% probability level. The ANOVA table is presented below.

Table 3: Analysis of Variance (ANOVA) for Number of Leaves

Source	DF	SS	MS	FC	FT1%	FT5%
Block	3	12.88	4.293333	4.93*	6.99	3.86
Treatment	3	76.81	25.60333	29.42**	6.99	3.86
Error	9	7.83	0.87			
Total	15	97.52				

Table 4: Comparison of Means (LSD)

Treatments	Mean	DIFFERENCE
Treatment 1	18.77*	5.75
Treatment 2	17.57*	4.55
Treatment 3	15.42*	2.4

Treatment 4 (check)

13.025

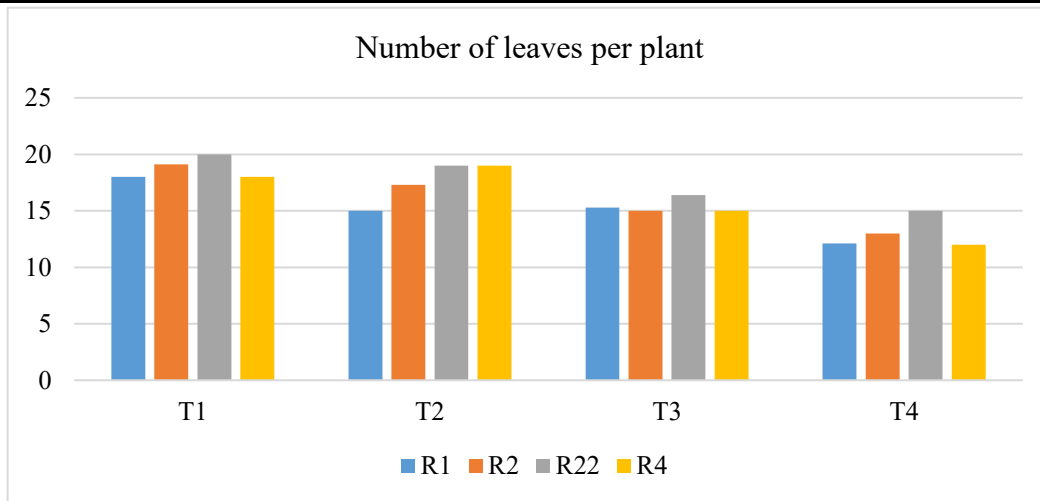


Figure 5: Effect of Different Nitrogen Levels on the Number of Leaves

Nitrogen plays a major role in the leaf width of spinach. Increased leaf width enhances photosynthesis, resulting in greater production of nutrients, which positively affects the number of leaves. Therefore, the number of leaves increased with the application of higher nitrogen doses compared to the control.

1. Leaf Length (cm)

Table 5: Leaf Length

Column1	R1	R2	R3	R4	TOTAL	AVERAGE
T1	28.6	29.9	30.2	30.6	119.3	29.82
T2	26.4	27.9	28.4	28.5	111.2	27.8
T3	26.2	27.1	27.6	28.6	109.5	27.37
T4	24.9	25	26.4	27.2		25.87

The tallest plant was observed in treatment T1 with the application of 120 kg nitrogen per hectare, measuring 29.6 cm. This difference was statistically significant at the 1% probability level. The ANOVA table is presented below.

Table 6: Analysis of Variance (ANOVA) for Leaf Length

C	DF	SS	MS	FC	FT1%	Ft5%
Block	3	9.485	3.161667	10.67**	6.99	3.86
Treatment	3	26.21	8.736667	29.50**	6.99	3.86
Error	9	2.665	0.296111			
Total	15	38.36				

Table 7: Comparison of Means (LSD)

treatment	Mean	DIFFERENCE
T1	29.675*	3.55

T2	27.425*	1.3
T3	27.375*	1.25
T4	26.125	

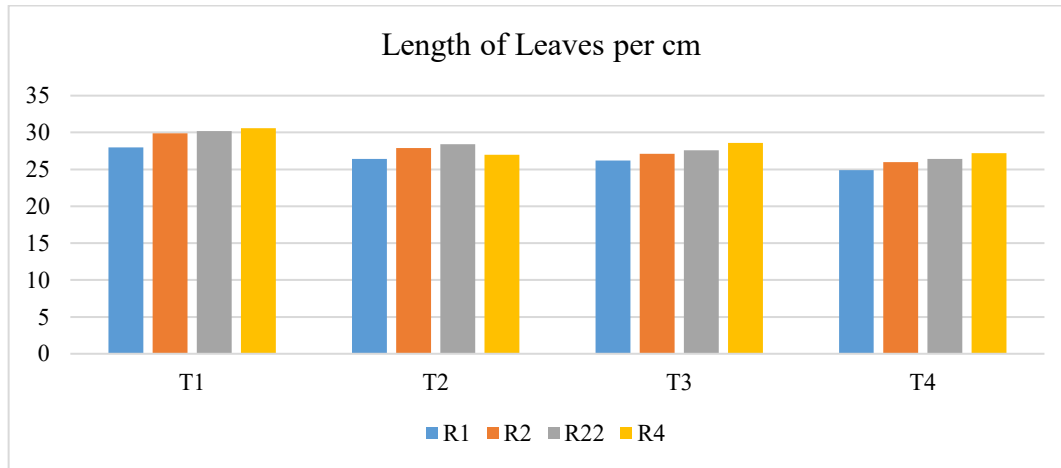


Figure 6: Effect of Different Nitrogen Levels on Leaf Length

Nitrogen plays an important role in protein synthesis and aids in cell division, which results in increased leaf length.

2. Leaf Width (cm)

Table 7: Leaf Width (cm)

Column1	R1	R2	R3	R4	TOTAL	AVERAGE
T1	10.5	9	10.1	10.5	40.1	10.025
T2	8.3	8.5	9.1	9	34.9	8.725
T3	8.3	8.5	9.1	9	34.9	8.72
T4	7.7	8.2	7.7	8.1	31.7	7.925

The greatest leaf width was recorded in treatment T1 with the application of 120 kg nitrogen per hectare, measuring 10.15 cm. This difference was statistically significant at the 1% probability level. The ANOVA table is presented below.

Table 8: Analysis of Variance (ANOVA) for Leaf Width

SOURCE	DF	SS	MS	FC	FT1%	Ft5%
BLOCK	3	3.586875	1.195625	4.59*	6.99	3.86
TREATMENT	3	10.96188	3.653958	14.04**	6.99	3.86
ERROR	9	2.340625	0.260069			
TOTAL	15	16.88938				

Table 9: Comparison of Means (LSD)

treatment	Mean	DIFFERENCE
T1	10.15	2.275*
T2	9.25	1.375*
T3	8.7	0.825ns

T4

7.875



Figure 7: Leaf Width (cm)

Nitrogen plays a role in protein synthesis, and protein assists in cell division, which leads to an increase in leaf width.

3. Yield (kg/ha)

Table 10: Yield (kg/ha)

Column1	R1	R2	R3	R4	TOAL	AVERAGE
T1	15930	14980	15600	15900	62410	15602.5
T2	14500	14700	14730	14850	58780	14695
T3	13600	13900	14240	13860	55600	13900
T4	13105	12504	12780	13102	51491	12872.75

The highest yield was obtained from the first treatment, with 15,575 kg per hectare. This difference was statistically significant at the 1% probability level. The ANOVA table is presented below.

Table 11: Analysis of Variance (ANOVA) for Yield

SOURCE	DF	SS	MS	FC	FT1%	Ft5%
BLOCK	3	656134	218711.3	3.89*	6.99	3.86
TREATMENT	3	15386738	5128913	91.25**	6.99	3.86
ERROR	9	505852	56205.78			
TOTAL	15	16548724				

Table 12: Comparison of Means (LSD)

treatment	Mean	DIFFERENCE
T1	15575 *	2673.5
T2	14637.5 *	1736

T3	13900 *	998.5
T4	12901.5	

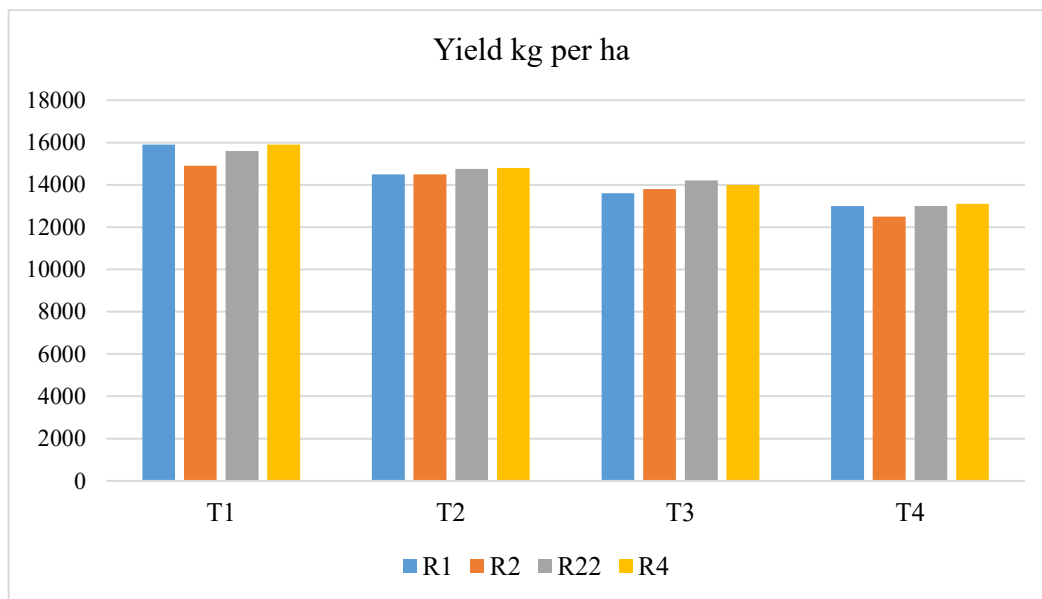


Figure 8: Effect of Different Nitrogen Levels on Yield

The yield of spinach is closely related to the number of leaves, leaf length, and leaf width. Since the highest values of leaf number, leaf length, and leaf width were recorded in the first treatment, the yield was also highest in this treatment.

4. Discussion

The significance of the research findings is examined and explained in the Discussion section. It compares the results with previous research, considers their ramifications, and connects the findings to the research questions or hypotheses. The study's shortcomings, surprising findings, and suggestions for further research may also be covered in this section. This is the section where the researcher demonstrates critical thinking and the work's broader importance.

Nitrogen application significantly increased the number of leaves per plant in spinach compared to the control treatment. Higher nitrogen levels enhanced vegetative growth by improving chlorophyll synthesis and photosynthetic activity, which promoted leaf initiation and development. Similar findings have been reported by Wahocho et al. (2015), who observed a maximum leaf number of 17.67 with the application of 120 kg nitrogen, and Zhang et al. (2014), who reported increased leaf number at higher nitrogen levels.

Nitrogen application significantly increased leaf length in spinach, with the highest leaf length observed under the application of 120 kg nitrogen per hectare. This improvement may be attributed to the role of nitrogen in protein synthesis and cell division, which promotes cell elongation and vegetative growth. The present findings are in agreement with those of Wahocho et al. (2015), who reported maximum leaf length under higher nitrogen application.

Applying nitrogen to spinach greatly expanded its leaf breadth. Protein synthesis, which aids cell division and so encourages leaf development, depends heavily on nitrogen. Higher nitrogen application resulted in the largest leaf breadth. These results are in line with other research; Darshan et al. (2019) found a maximum leaf width of 9 cm with 80 kg nitrogen, while Wahocho et al. (2015) reported a maximum leaf width of 9.69 cm at 120 kg nitrogen.

The application of nitrogen greatly enhanced spinach output; treatment T1 had the best yield (15,575 kg/ha). Since better vegetative development encourages greater biomass accumulation, gains in leaf number, length, and width are directly linked to increases in yield. These findings are in line with earlier research; Goodarzi et al. (2020) found that applying 100 kg of nitrogen produced a yield of 15,000 kg/ha, demonstrating the beneficial impact of nitrogen on spinach productivity.

5. Conclusion

Different levels of nitrogen had a significant effect on the growth and yield of spinach. The results showed that treatment T1 – 120 kg N/ha had a greater impact on spinach growth and yield compared to the control. The maximum number of leaves was 18.77, leaf length was 29.67 cm, leaf width was 10.15 cm, and the yield was 15,575 kg/ha. The lowest yield was recorded in T4 – 0 kg N/ha, with 13.025 leaves per plant, leaf length of 26.12 cm, leaf width of 7.8 cm, and a yield of 12,901.5 kg/ha. Therefore, treatment T1 – 120 kg N/ha was the most effective for spinach growth and yield.

Recommendations

- The most effective nitrogen level for spinach growth and yield is 120 kg/ha, which significantly improves spinach development and production.
- Applying nitrogen beyond 200 kg/ha negatively affects spinach growth and yield.
- Excessive nitrogen application increases nitrate content in spinach, making it unsuitable for consumption.

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