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Effect of different nitrogen levels on growth and yield of radish

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Abstract
Nitrogen (N) is a key nutrient influencing radish (Raphanus sativus L.) growth, root development, and yield. A field experiment with four nitrogen levels (0, 50, 60, 70 kg/ha) was conducted to assess their impact on growth, flowering, and yield traits. Vegetative parameters such as plant height, number of leaves, and leaf length improved with increasing N, enhancing photosynthetic capacity. Root length, girth, and weight were highest at 60 kg N/ha, which produced the maximum root yield (\~376 q/ha). However, excessive N (70 kg/ha) delayed flowering and reduced seed yield. The best seed yield (\~7.3 q/ha) and earliest flowering occurred at 50 kg N/ha. Thus, 50-60 kg N/ha emerged as the optimal range for maximizing both root and seed productivity. These results highlight the importance of balanced nitrogen management for efficient radish production in Punjab's sandy loam soils.

Keywords: Radish, nitrogen, growth, root yield, seed yield, flowering

Introduction
Radish is a quick-maturing root crop valued for its nutritional content and short growth cycle. Nitrogen plays a vital role in its growth, being essential for chlorophyll, protein, and enzyme synthesis. N deficiency results in stunted plants, poor foliage, and low-quality roots, while adequate N improves plant height, leaf number, root development, and overall yield. Prior studies (Bilekudari *et al*., 2005; Akoumianakis *et al*., 2011; Jilani *et al*., 2010) [3, 2, 6] confirm that nitrogen enhances vegetative growth and root size. However, excessive N can delay flowering and reduce crop quality, making optimal N dosing essential. Moderate nitrogen levels are generally recommended to avoid over-vegetation. In Punjab's sandy loam soils, where nitrogen retention is low, precise N management is especially important. This study evaluates the effect of different nitrogen levels (0, 50, 60, 70 kg/ha) on radish growth, root development, and reproductive traits to determine the ideal N dose for maximizing root yield and seed productivity under local conditions.

Materials and Methods
The experiment was conducted during the winter (rabi) season of 2024-25 at the Research Farm of Guru Kashi University, Bathinda, Punjab. The soil type was sandy loam with low fertility. A split-plot design was used, where radish variety served as the main plot and nitrogen level as the sub-plot. Four nitrogen treatments were applied: 0 (control), 50, 60, and 70 kg N/ha. Five radish varieties—Punjab Safed Mooli-2, Pusa Chetki, Punjab Pasand, Japanese White, and GKU Selection—were included. Each treatment was replicated three times. Nitrogen was applied as urea in two equal splits: half at sowing and half after 3-4 weeks to ensure sustained availability. Standard agronomic practices were followed throughout. Growth and yield observations were recorded from five randomly selected plants per plot. Plant height was measured from base to tallest leaf, and mature leaves per plant were counted. Leaf length was measured from the leaf base to tip. Root length and girth were recorded using calipers, and root weight (excluding leaves) was taken post-harvest. Yield per plot was extrapolated to quintals per hectare. Flowering observations included days to first (1%) and full (100%) bloom. Seed yield was recorded per plant and per hectare after drying.

Results and Discussion

Growth Parameters (Plant Height, Leaves, Leaf Length)

Nitrogen fertilization significantly influenced radish vegetative growth. Plants grown without nitrogen (0 kg/ha) were the shortest and produced the fewest and smallest leaves, while those receiving moderate nitrogen were visibly more vigorous. Plant height showed a positive trend with increasing nitrogen, ranging from \~22 cm in the control to \~25 cm at 70 kg N/ha (Table 1). Though differences in height were not statistically significant, the pattern indicates that nitrogen supports vegetative development by promoting cell division and elongation. The number of leaves per plant increased significantly with nitrogen application ($p<0.05$), peaking at 50 kg N/ha with about 12 leaves—roughly two more than the control. These results align with Akoumianakis *et al*. (2011) [2], who found that nitrogen enhances canopy growth.

Leaf length was also improved by nitrogen; plants at 50-70 kg N/ha developed the longest leaves (\~25 cm), compared to \~21-22 cm in the control. However, this effect was not statistically significant (p 0.05), likely due to varietal differences. GKU Selection had the longest leaves across treatments. Overall, applying 50-60 kg N/ha led to improved vegetative traits—slightly taller plants, significantly more leaves, and longer foliage—which together enhance photosynthetic capacity. These improvements can support better root growth and yield, reinforcing nitrogen's vital role in radish vegetative development.

Table 1: Plant Growth Characteristics under Different Nitrogen Levels. Each value is the mean of five plants (varieties pooled).

Nitrogen Level (kg/ha)	Plant Height (cm)	Leaves per Plant	Leaf Length (cm)
0 (Control)	22.0	10.1	21.6
50	24.0	11.7	24.9
60	24.5	12.4	24.5
70	25.0	12.2	25.3

Nitrogen effects on growth: Nitrogen significantly enhanced leaf number and size in radish due to its role in chlorophyll formation and vegetative growth. Plants receiving 50-60 kg N/ha developed greener, broader foliage, improving light interception and photosynthetic activity, which supported better root development. However, at 70 kg N/ha, leaf production plateaued or slightly declined (Table 1), suggesting excessive nitrogen may lead to vegetative overgrowth or mild toxicity. Khanal *et al*. (2022) [7] similarly found that beyond 80 kg N/ha, further gains in radish growth were minimal. Genetic differences also influenced leaf development; for example, Japanese White produced the most leaves per plant. Despite varietal variation, nitrogen remained a major factor driving vegetative vigor. The foliage developed under 50-60 kg N/ha was likely key to higher root yield by increasing assimilate availability. Thus, moderate nitrogen fertilization supports a strong vegetative framework essential for optimal root formation without the drawbacks of excessive vegetative delay or nutrient imbalance.

Root Length and Girth

Nitrogen significantly influenced radish root development, especially root length and girth. The longest roots were observed at 60 kg N/ha, averaging ~36.5 cm, compared to ~29.7 cm in the control, indicating a ~23% increase (Table 2). This suggests that adequate nitrogen facilitates root elongation by supplying nutrients during the critical root expansion stage. Poudel *et al*. (2018) [12] also reported that nitrogen enhances radish root length, especially at higher doses. In this study, 60 kg N/ha emerged as the optimal rate for root length, while 70 kg N resulted in slightly shorter roots (~33 cm), likely due to excessive top growth that diverted resources from the root zone.

Root girth followed a similar trend. The thickest roots (≈12.1 cm diameter) were recorded at 60 kg N/ha, while control and 50 kg N/ha treatments produced thinner roots (11.0-11.5 cm). Statistically, 60 kg N significantly improved root girth over lower N levels. This improvement is attributed to enhanced carbohydrate availability from increased photosynthesis, which supports root swelling. High nitrogen likely promoted a stronger source-sink relationship, enabling efficient storage in the root.

Interestingly, 70 kg N/ha led to a slight decline in girth (~11.7 cm), suggesting diminishing returns or imbalanced growth. Excessive nitrogen can increase foliage at the expense of root bulking, limiting the size of marketable roots. These results align with past findings that moderate nitrogen enhances both root size and quality. Overall, 60 kg N/ha was ideal for developing long, thick roots, balancing vegetative growth with optimal root formation, and improving marketable traits in radish.

Table 2: Root Development under Different Nitrogen Levels. Root length and girth (diameter) per plant are averages across varieties.

Nitrogen Level (kg/ha)	Root Length (cm)	Root Girth (cm)
0 (Control)	29.7	11.5
50	34.0	11.2
60	36.5	12.1
70	33.0	11.7

Improvements in root dimensions with optimal nitrogen align with previous findings. Pervez *et al*. (2004) [11] reported increased radish root length and diameter with N application, driven by extended root growth and enhanced photosynthesis. In our study, all varieties responded similarly to nitrogen, despite differences in absolute root size. GKU Selection produced roots over 40 cm under N treatment, reflecting its genetic potential, as noted by Sharma *et al*. (2020) [13]. Root length and girth improved consistently up to 60 kg N/ha, after which gains declined. Thus, 60 kg N/ha appears optimal for maximizing root size across varieties without the negative effects of over-fertilization.

Root Weight (Biomass) and Yield

Nitrogen application significantly improved radish root size, weight, and total yield. Root weight per plant increased from 0.27 kg in the control to 0.33 kg at 60 kg N/ha (Table 3), a \~22% rise. Both 50 kg and 70 kg N/ha yielded slightly less (\~0.30-0.32 kg), suggesting 60 kg N is optimal. Nitrogen enhances carbohydrate accumulation in roots, increasing fresh weight. Excessive N (70 kg) didn't improve root weight, likely due to imbalanced vegetative growth. This supports Gupta *et al*. (2017) [4], who noted that moderate N improves root mass and quality in root crops.

Total root yield followed a similar trend. The control yielded 182 q/ha, while 60 kg N/ha reached 376.5 q/ha—more than double. Yield at 50 kg N/ha was \~300 q/ha, and

70 kg N/ha yielded slightly less (\~340 q/ha). These results confirm nitrogen as the limiting factor for productivity on the sandy loam soil. The yield gains were statistically significant (p<0.01), with 60 kg N balancing vegetative and root growth. Punjab Pasand showed the highest yield among genotypes (>313 q/ha). Comparable increases have been reported by Jilani *et al*. (2010) [6], who observed root yield doubling with added N. Our maximum yield surpasses many literature values, reflecting a strong N response in this environment. Applying more than 60 kg N offers minimal benefit and could increase nitrate leaching risks (Ullah *et al*., 2023) [15].

Table 3: Root Weight and Yield under Different Nitrogen Levels. Root weight is per plant (without leaves); total root yield is given in quintals per hectare (q/ha).

Nitrogen Level (kg/ha)	Root Weight/Plant (kg)	Root Yield (q/ha)
0 (Control)	0.27	182
50	0.30	300
60	0.33	376
70	0.32	340

Nitrogen plays a vital role in enhancing radish yield and quality. It boosts leaf area and photosynthesis, increasing carbohydrate production for root storage. In our study, yield improved significantly from 0 to 50-60 kg N/ha (Table 3), confirming that native soil N was insufficient. However, 70 kg N/ha slightly reduced yield, likely due to excessive vegetative growth or delayed root development. Similar results were reported by Ahmad *et al*. (2019) [1]. Additionally, 60 kg N/ha produced the sweetest roots, with total soluble solids (TSS) reaching \~4.7 °Brix, as also noted by Gupta and Verma (2021) [5]. These findings emphasize that moderate nitrogen (50-60 kg/ha) optimizes both root yield and quality, while excess N may reduce efficiency and quality, underscoring the need for balanced nutrient management.

Flowering and Seed Production

Nitrogen levels significantly influenced radish flowering and seed yield. The control (0 kg N/ha) initiated flowering earliest (\~31.5 days), likely as a stress response, while 60 kg N/ha delayed flowering to \~36.6 days due to extended vegetative growth. Interestingly, 70 kg N/ha showed slightly earlier flowering (\~34.4 days), indicating a possible threshold effect. For full bloom, 50 kg N/ha was optimal (\~50.0 days), even faster than the control (52.8 days), whereas 70 kg N/ha delayed it further (\~53.2 days) (Table 4). Seed yield was highest at 50 kg N/ha (7.3 q/ha) and lowest in the control (2.6 q/ha). Higher N doses (60-70 kg) reduced yield, likely due to delayed flowering and vegetative dominance. Seed yield per plant peaked at 50 kg N (\~15.8 g/plant). These results align with Sharma and Kumar (2019) [13] and Patel *et al*. (2021) [10], emphasizing optimal N for seed production. Varietal differences were also observed; Pusa Chetki flowered earliest (\~30.5 days), while Japanese White gave the highest seed yield (>7 q/ha). Thus, 50 kg N/ha is ideal for seed-focused radish cultivation.

Table 4: Flowering and Seed Yield under Different Nitrogen Levels. Flowering times are days from sowing; seed yield is given in quintals per hectare (q/ha).

Nitrogen Level (kg/ha)	Days to First Flowering	Days to 100% Flowering	Seed Yield (q/ha)
0 (Control)	31.5	52.8	2.6
50	35.3	50.0	7.3
60	36.6	51.1	6.5
70	34.4	53.2	5.0

Table 4 highlights nitrogen's critical role in radish seed production. The control (0 kg N/ha) flowered earliest but produced the lowest seed yield due to poor plant vigor. In contrast, excessive nitrogen (70 kg N/ha) delayed flowering and reduced seed output. Optimal seed yield (\~7 q/ha) occurred at 50 kg N/ha, with Japanese White performing best. While 60 kg N/ha also gave reasonable yield (\~6-6.5 q/ha), it slightly delayed flowering. Early-flowering varieties like Pusa Chetki may suit faster harvests but yield less than Japanese White. Therefore, 50 kg N/ha offers the best balance of flowering timing and seed productivity. These findings align with previous research (Ahmad *et al*., 2019; Gupta & Verma, 2021; Sharma & Kumar, 2019) [1, 5], emphasizing that nitrogen must be tailored to production goals.

Conclusion

This study confirms that nitrogen significantly affects radish growth, root yield, and seed production. Applying 50-60 kg/ha of nitrogen resulted in optimal plant performance, producing vigorous growth, large roots (>36 cm length, \~12 cm girth), and the highest root (300-376 q/ha) and seed yields (\~7 q/ha). While N deficiency reduced growth, excessive N (70 kg/ha) delayed flowering and slightly reduced yields. Thus, 60 kg/ha is ideal for root production, and 50 kg/ha is best for seed yield. These findings support the use of balanced nitrogen for efficient radish cultivation and highlight the need for site-specific nutrient management to maximize yield and crop quality.

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