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Effect of Different Nitrogen Rates and Plant Densities on Corn Growth, Yield, and Weed Composition in Laghman Province

Obaidurahman Zahid[1], Samiullah Safi[2] and Jamal Tanha[3]

[1,2,3]Department of Agronomy, Faculty of Agriculture, Laghman University, Afghanistan

E-mail: obaidzahid10@gmail.com (corresponding author)

ABSTRACT

Applying sufficient nitrogen is a key factor for plant growth and yield development. A field study was conducted in 2022 at the research farm of the Agriculture Faculty, Laghman University, to assess the effects of two planting densities, D1 (75 cm x 20 cm) and D2 (65 cm x 20 cm), and four nitrogen rates, N1 (120 kg N/ha), N2 (140 kg N/ha), N3 (160 kg N/ha), and N4 (180 kg N/ha), on the growth and yield parameters of the corn variety GWG888, as well as on weed composition. Results showed that both nitrogen rates and planting densities significantly affected corn growth, yield, and weed composition. Plant height, leaf count, cob count, cob length, and dry matter yield were maximized with a nitrogen rate of 160 kg N/ha (N3). Meanwhile, the highest weed species diversity and population were observed at 180 kg N/ha (N4). The higher planting density (65 cm x 20 cm) reduced plant height and leaf number but significantly increased dry matter yield. These findings suggest that the optimal nitrogen rate for improved corn growth and yield in Laghman Province is 160 kg N/ha with a planting density of 75 cm x 20 cm.

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Introduction

After wheat and rice, corn (*Zea mays*) is the third most important cereal crop. It is used as daily food, livestock feed, and as a raw material in industry (Harris et al., 2007). Numerous factors contribute to low corn production, one of the most impactful being fertilizer application, which can significantly increase yield per unit area (Ayub et al., 2002). Nitrogen (N) management is essential in corn production. N fertilizers have been shown to enhance plant productivity, agronomic attributes, and overall crop yields (Oliveira et al., 2016; Yu-Kui et al., 2009). Corn grain yield generally increases with N application on low-fertility soils up to an optimal threshold, after which further N application has no effect or may even reduce yield (Gökmen et al., 2001).

Agricultural practices, including seed rates, plant density, and fertilizer application, influence the crop environment, impacting growth and yield. To achieve sufficient growth and production, maintaining optimal plant population and N levels is essential to fully utilize resources like fertilizers, sunlight, and soil moisture (Tajul et al., 2013). Using N in corn production requires appropriate timing, adequate application rates, and sufficient quantity to optimize yield. Research has shown that optimal corn yields are achieved with N applications ranging from 140 to 250 kg N/ha. The highest leaf area, plant height, 1000-kernel weight, biological yield, grain yield, and harvest index (42%) were recorded at 160 kg N/ha (Anwar et al., 2018).

Lamptey et al. (2018) observed that increased N rates improved forage quality in corn, raising crude protein while reducing acid detergent fiber and neutral detergent fiber. Additionally, optimal plant population density promotes balanced growth, maximizing surface and subsurface development, solar radiation absorption, and nutrient use (Mahdi & Ismail, 2015). Increased plant density enhances light capture within the canopy, though higher densities may reduce corn yield due to shading (Buren, 1970). Planting techniques also significantly influence maize yield, yield components, plant population, and hybrid response to various planting densities (Moussavi et al., 2011).

Crop nutrient management is essential for weed control, as weed growth competes closely with corn for resources like light, water, and nutrients. Weed competition is a major challenge in corn production worldwide. Balanced fertilization promotes crop growth, creating a denser crop canopy that limits light availability for underlying weed populations, thus reducing weed species diversity (Tang et al., 2014). In regions with low soil fertility and plant density, such as Afghanistan, enhancing corn growth and yield requires increased nitrogen rates and plant density. Therefore, this experiment was conducted to evaluate whether the current recommended nitrogen rates and planting densities for corn are adequate or require adjustment.

Literature Review

Nitrogen is a vital nutrient for plant growth, significantly impacting grain productivity (De Queiroz et al., 2011). Optimized management practices in agricultural systems are crucial to maximizing yield, minimizing nitrogen loss, and improving nitrogen uptake efficiency. This involves synchronizing nitrogen fertilizer applications with crop demand regarding timing, rate, and method. Additionally, split application based on leaf chlorophyll and plant nitrogen levels can enhance nitrogen use efficiency (Cambouris et al., 2016). Inappropriate nitrogen application rates can result in over- or under-fertilization, with economic and environmental consequences. Although specific nitrogen requirements for corn vary by region, optimal yields are typically achieved with 140 to 250 kg N/ha (Anwar et al., 2018).

Corn, typically planted in wide-spaced rows, is sensitive to plant density. Modern corn hybrids often do not yield well at high densities and usually produce only one ear per plant (Sangoi & Bibliográfica, 2000). Plant density per unit area is a significant yield determinant. Increased density promotes solar radiation absorption within the canopy, improving grain yields (Moussavi et al., 2011). Optimal corn population yield varies with environmental conditions, including water, soil fertility, maturity, planting date, and row spacing. Exceeding optimal density may adversely affect cob development and lead to barrenness (Sangoi & Bibliográfica, 2000).

Weed growth closely affects crop productivity. Weed competition, especially at early growth stages, can severely impact corn yield, causing losses of 60-82% (Imoloame & Omolaiye, 2017). Evans et al. (2003) found that increased weed interference significantly reduced cob formation and 100-seed weight, with seed count per cob being the most affected yield component.

Methods and Materials

In 2022, a field experiment was conducted at the Agriculture Faculty research farm at Laghman University to study the effects of two planting densities and four nitrogen rates on the growth, yield characteristics, and weed composition of the fodder corn variety GWG888. The experimental site was plowed and rotated before sowing to ensure optimal soil conditions. Two seeds per hill were initially planted, then thinned to one plant per hill. Each subplot comprised three rows with 35 cm inter-row spacing and a 50 cm buffer zone between subplots. Drip irrigation was applied after sowing to support germination and establish plant stands.

The split-plot design experiment included four nitrogen rates (subplots) and two planting densities (main plots), with four replications. The total experimental area was 39 m x 14.6 m.

Growth parameters were recorded in the middle rows to avoid border effects. Data on plant height, leaf count, cob count, cob length, and dry weights of leaves, stems, cobs, and total plants were collected 4, 6, 8, 10, and 12 weeks after planting. At 13 weeks, above-ground parts were harvested, and dry weights were recorded. Weed composition was assessed at 12 weeks using three quadrats per plot, where weeds were collected, identified by species, counted, and converted to counts per square meter.

ANOVA was performed to assess treatment effects, with mean comparisons conducted using the least significant difference (LSD) at $P<0.05$ in SAS software (version 9.4, SAS Institute Inc., North Carolina, USA).

Results and Discussion

Plant height and the number of leaves were strongly influenced by nitrogen rates and plant densities, as well as cob number and cob length (Table 1).

Table 1. Effect of Different Nitrogen Rates and Plant Densities on Plant height, number of leaves, cob number, and length.

Treatments	Plant height (cm)	Leaves number	Cob number	Cob length (cm)
Nitrogen rates				
N1	190.92 b	11.63 b	1.13 a	18.67 c
N2	192.47 b	11.76 ab	1.16 a	19.37 b
N3	196.93 a	11.92 a	1.21 a	20.37 a
N4	193.78 ab	11.73 ab	1.18 a	20.2 b
Density				
D1	192.32 b	11.71 a	1.16 a	19.52 a
D2	194.78 a	11.81 a	1.18 a	19.77 a

Significant difference in means within the column in the same letters at P≥0.05. N1= 120 Kg N/ha^{-1}, N2= 140 Kg N/ha^{-1}, N3= 160 Kg N/ha^{-1}, N4= 180 Kg N/ha^{-1}, D1= (65cm x 20cm), D2= (75cm x 20cm).
WAS= Week After Sowing.

The highest plant height, leaf count, and cob length were observed with N3 (160 kg N/ha), followed by N4 (180 kg N/ha), whereas N1 (120 kg N/ha) produced the lowest values. Higher growth attributes were found in the lower plant density (75 cm x 20 cm) compared to the higher density (65 cm x 20 cm). Overall, corn growth was optimal at 160 kg N/ha, likely due to enhanced protein production from nitrogen, which supports increased plant height and other growth parameters. Although lower plant density D2 (75 cm x 20 cm) produced greater plant height and leaf area, the number of leaves, cob count, and cob length were not significantly different between the two densities. The reduced leaf area at higher plant density could be attributed to limited carbohydrate availability due to high competition among plants, which aligns with findings from Sher et al. (2018).

The dry matter (DM) yields of leaves, stem, cob, and total plant were significantly impacted by nitrogen rates and plant densities (Table 2).

Table 2. Effect of Different Nitrogen Rates and Plant Densities on Leaf, stem, cob, and Total Plant Dry Matter Yield (Tons/ha)

Treatments	Leaf DM yield (T/ha)	Stem DM Yield (T/ha)	Cob DM Yield (T/ha)	Total DM Yield (T/ha)
Nitrogen rates				
N1	3.22 c	6.01 c	15.03 c	24.27 c
N2	3.5 b	6.56 b	15.38 b	25.45 b
N3	3.75 a	6.89 a	16.16 a	26.8 a
N4	3.54 b	6.62 b	15.43 b	25.6 d
Density				
D1	3.54 a	6.57 a	15.56 a	25.68 a
D2	2.47 b	6.46 b	15.44 b	25.38 b

Significant difference in means within the column in the same letters at P≥0.05. N1= 120 Kg N/ha^{-1}, N2= 140 Kg N/ha^{-1}, N3= 160 Kg N/ha^{-1}, N4= 180 Kg N/ha^{-1}, D1= (65cm x 20cm), D2= (75cm x 20cm).

WAS= Week After Sowing.

The highest DM yield was observed at a planting density of 65 cm x 20 cm with 160 kg N/ha. The next highest yields were achieved in descending order with 180 kg N/ha, 140 kg N/ha, and 120 kg N/ha. This trend suggests that DM accumulation is closely linked to leaf area index, which increases with higher plant population density (Fromme et al., 2019). Nitrogen fertilizer also increased weed species diversity and population (Table 3), with the highest weed population observed at 180 kg N/ha.

Table 3. Main Effects of Different N Rates and Plant Density on Number of Weed Species and Population.

Treatments	Number of Weed Species	Weed Population
Fertilizer Application Regimes		
N1	14.12 c	218.37 b
N2	15 bc	227.75 b
N3	15.37 b	243.5 a
N4	16.25 a	247.25 a
Density		
D1	15.12 b	231.93 b
D2	15.25 a	236.5 a

Significant difference in means within the column in the same letters at $P \geq 0.05$. N1= 120 Kg N/ha^{-1}, N2= 140 Kg N/ha^{-1}, N3= 160 Kg N/ha^{-1}, N4= 180 Kg N/ha^{-1}, D1= (65cm x 20cm), D2= (75cm x 20cm).
WAS= Week After Sowing.

As nitrogen rates increased, so did the number of weed species, as elevated soil nitrogen promotes the growth of many weed species. Thus, nitrogen fertilizer application may unintentionally enhance weeds' competitiveness in crop systems (Murphy & Lemerle, 2006). These results suggest that corn production can be significantly improved by using a population density of 75 cm x 20 cm with a nitrogen rate of 160 kg N/ha in Laghman province.

Corn is a primary fiber source, serving as a dietary staple for humans, with around 63% of global corn production used as food, while the remainder supports animal protein production. This usage pattern varies by region: in developed nations, about 44% of corn produced is used for human consumption, while in developing nations, this rises to 77%, with the balance used for animal feed. Feed costs are a major expense in intensive livestock production (Obaidi et al., 2012).

Though corn is a major crop in Afghanistan, its uses differ from those of wheat and rice. Corn is mainly used as livestock feed, though corn flour is a staple for bread-making in some regions. A key advantage of corn is its adaptability across ecological zones, allowing it to be cultivated nationwide (Abdul Wahab & Shah, 2023).

Corn is strategically important in Afghanistan, with the potential to triple its benefits through increased income, food security, and employment. As a multipurpose crop, corn is a staple for more than half of the global population (Obaidi et al., 2012). Corn is an alternative food source when traditional cereals like wheat and rice are in short supply. Additionally, it plays a significant role in poultry feed, biofuel production, animal feed, and industrial applications (Sibhatu et al., 2015). Therefore, corn ranks as Afghanistan's third most important cereal crop, accounting for 4.9% of cereal production and approximately 1.1% of agricultural value added (Abdul Wahab & Shah, 2023).

Conclusion

Applying an optimal nitrogen rate (160 kg N/ha) resulted in maximum plant height, leaf count, cob length, and dry matter yield. The highest weed species count and population were observed with 180 kg N/ha. These findings indicate that a nitrogen rate of 160 kg N/ha at a planting density of 75 cm x 20 cm enhances corn growth and yield in Laghman province.

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