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Effects of Varied Nitrogen Fertilization Rates on Yield and Growth parameters of Hybrid Maize under agro-climatic conditions of Nangarhar, Afghanistan

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ABSTRACT: Nitrogen is one of the most essential nutrients influencing the growth, development, and productivity of maize (*Zea mays L.*). This study was conducted to evaluate the effects of different nitrogen fertilization rates on the growth and yield performance of hybrid maize under the agro-climatic conditions of Nangarhar, Afghanistan. The experimental treatments consisted of four nitrogen fertilization rates; 0, 130, 160 kg and 190 kg N ha⁻¹, Nitrogen fertilizer was applied in form of Urea (46%N) in three split application ¼ dose at sowing, ½ at knee high stage and ¼ at tasseling stage. The experiment was conducted as randomized complete block design (RCBD). The results showed that the application of 190 kg N ha⁻¹, produced significantly higher values than the other treatments for plant height (244 cm), stem diameter (9.92 cm), number of leaves per plant (15.83), cob length (22 cm), number of grain per cob (455), grain weight per cob (133.17 g), 1000-grain weight (300 g), biological yield (808 g), fresh cob yield (8.33 kg), fresh net grain yield per cob (153.17 g). The lowest values were recorded under the control treatment (0 kg N ha⁻¹) across all plant growth and yield parameters.
Therefore, this article recommends 190 kg N ha⁻¹ for farmers in the region and in similar climatic regions to achieve good maize growth and high yields.

KEYWORDS: maize (*Zea mays L.*), nitrogen, yield components.

1. INTRODUCTION

Maize (*Zea mays L.*) is the world's most extensively grown cereal and primary staple food crop in many developing countries, including Afghanistan (Kandil, 2013). Maize originated in Central America, especially Mexico, more than 7,000 years ago and has since expanded globally (Hailare, 2000; Zamir et al., 2013). Currently, maize is cultivated across a wide range of agro-climatic conditions around the world and is used as a staple food in addition to supporting the economic well-being of a large population, particularly in developing nations (Seshu et al., 2014).

Due to its high yield potential and adaptability to various agro-climatic conditions, maize is widely cultivated in irrigated and rainfed areas (Imran et al., 2015). The crop grows effectively in areas with an annual rainfall of more than 600 mm where rainfall is evenly distributed (Ahmad et al., 2018). Maize is also known as the "miracle crop" due to its high yield potential, which is the highest among all cereals (Ali & Anjum., 2017).

Maize (*Zea mays L.*) is one of the world's most important cereal crops and plays a vital role in global food security, animal feed, and industrial production. It is cultivated on approximately 200 million hectares worldwide and is the leading cereal crop in terms of global production (FAOSTAT, 2024; Erenstein et al., 2022). In addition to human consumption, maize is also widely used in livestock feeding and for manufacturing products like starch, oil, and biofuels (Obaidi et al., 2012).

Maize is widely cultivated across Asia, particularly in India, where it plays a vital role in food security and agricultural livelihoods. Seasonal climatic conditions, including rainfall distribution, temperature, and solar radiation, strongly influence maize growth and grain yield. Excessive rainfall, drought, and heat stress during critical growth stages can reduce productivity, whereas favorable environmental conditions with adequate sunlight, optimum soil moisture, and effective pest and disease management enhanced maize yield. (Prasanna et al., 2021; Yasin et al., 2022).

Maize is one of the most important cereal crops in Afghanistan after wheat and rice. However, maize productivity in Afghanistan remains lower than the global average. According to FAOSTAT (2024), the average maize grain yield in Afghanistan was approximately 2.4 t ha⁻¹, whereas the global average maize yield was about 5.8 t ha⁻¹. This yield gap is mainly associated with

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inadequate nutrient management, limited adoption of improved agronomic practices, and environmental constraints (Liu et al., 2022). Therefore, improving nitrogen management and adopting suitable crop production practices are essential for enhancing maize productivity under Afghan agro-climatic conditions.

Nitrogen is an essential nutrient for agricultural crops that has a significant role in growth, development, yield improvement, and productivity of maize (Gul et al., 2021). Nitrogen is also regarded as a key element influencing maize growth and grain yield (Adhikari et al., 2021). It is a major component of chlorophyll and proteins and directly influences leaf area expansion and grain structure (Torbert et al., 2011).

Maize yield generally increases with higher nitrogen application because nitrogen plays a vital role in chlorophyll formation, photosynthesis, protein synthesis, and other physiological processes that contribute to plant growth and grain development. Appropriate nitrogen supply improves nitrogen metabolism and enhances maize yield and yield components (Yue et al., 2022; Ahmad et al., 2021). Also, the positive response of maize components to nitrogen application and provision of adequate amounts of nitrogen are considered essential for achieving the highest yields (Sorkhi & Fateh 2014).

Adequate nitrogen fertilization is essential for maximizing maize grain yield and improving nitrogen use efficiency. Appropriate nitrogen application rate and timing enhanced crop performance, whereas inadequate nitrogen supply can reduce maize productivity (Davies et al., 2020). Various studies have indicate that nitrogen has a considerable impact on plant height, leaf number, biomass accumulation, and overall yield (Savi et al., 2013). Therefore, efficient nitrogen management is very important for increasing and sustaining maize production (Barutcular et al., 2016).

This study aimed to assess the impact of different nitrogen fertilization rates on maize growth and yield under local agro-climatic conditions in Nangarhar, Afghanistan. The objective of this study was to evaluate the response of maize growth to different nitrogen application rates under the agro-climatic conditions of Nangarhar Province, Afghanistan. Specific Objectives to evaluate the relationship between nitrogen application rates and crop performance through correlation and regression analysis, and to illustrate the effects of different nitrogen levels on maize grain yield and nitrogen use efficiency. To determine the optimal nitrogen level.

2. METHOD AND MATERIAL

2.1 Study Area

This research was conducted during the 2025 growing season under the agro-climatic conditions of Batikot District, Nangarhar Province, Afghanistan. The experiment was established at two different farmer fields within the district, designated as Location A and Location B. Both locations were selected to represent the local agro-climatic conditions of the study area. The same experimental design, nitrogen fertilization treatments, and crop management practices were applied at both locations. Data collected from the two locations were combined for statistical analysis.

2.2 Experimental Design and Treatments

The experiment was conducted using a randomized complete block design (RCBD) with four treatments and three replications. The treatments including four nitrogen rates 0 kg N ha^{-1}, 130 kg N ha^{-1}, 160 kg N ha^{-1}, 190 kg N ha^{-1}, Urea (46% N) was used as the nitrogen source. Nitrogen fertilizer was applied in three split doses ¼ at the time of sowing, ½ at knee-height stages and ¼ tasseling stage. Urea was applied using the side-dressing method.

2.3 Crop Management

All treatments were planted with the local variety Zoodras (released by ARIA) (Obaidi et al., 2012). Planting holes were made using a pointed wooden stick similar to traditional tools used in Central and South America. Seeds were then dropped into the holes and covered with soil by foot. Maize was planted on 28 May 2025 at the depth of 5 cm with 50 cm row and 20 cm plant-to-plant spacing and harvested on 9 September 2025. The size of each plot was 3 m × 3 m=9 m^2). Each row contained 15 plants, resulting in a total of 90 plants per plot. A spacing of 90 cm was maintained between adjacent blocks to minimize treatment interference and ensure proper field management. To minimize border effects, no samples or observations were taken from the border rows, and data were collected only from the inner rows of each plot.

Three manual weedings were carried out during the maize growings period. The first weeding was performed at 25 days after sowing (DAS), while the subsequent weeding's were conducted at 25-day intervals using manual methods. Irrigation was applied manually at intervals of 7–12 days according to crop requirements. A total of ten irrigations were provided throughout the crop growing period.

2.4 Soil Sampling and Analysis

Before sowing, composite soil samples were collected from the 0–15 cm depth of the experimental field. Soil physicochemical analysis was carried out at the Sheshambagh Agricultural Experiment Station, Nangarhar Province, Afghanistan. Soil pH and electrical conductivity (EC) were determined using a digital pH/EC meter, soil texture was determined by the hydrometer method, available phosphorus was determined by the Olsen method, available nitrogen by the Kjeldahl method, and available potassium by flame photometry following standard laboratory procedures. The physicochemical properties of the experimental soil are presented in Table 1.

Table 1. Physiochemical properties of the topsoil (0–15 cm) at the experimental site.

Sand (%)	Silt (%)	Clay (%)	Texture class	Electrical Conductivity (dSm -1)	Soil pH	Available N (ppm)	Available P2 O5 (ppm)	Available K (ppm)
74.67	13.33	10.44	Sandy Loam	0.021	8.7	12.50	10.2	*85*

2.5 Meteorological Data

Monthly meteorological data, including mean temperature, maximum temperature, minimum temperature, rainfall, relative humidity, wind speed and solar radiation, were obtained from the NASA POWER database for Batikot District, Nangarhar Province, Afghanistan (Latitude 34.29°N, Longitude 70.76°E). The meteorological conditions during the study period are presented in Table 2.

Table 2. Monthly meteorological parameters of Batikot, Nangarhar, Afghanistan (May–September 2025)

Month	Mean Temp (°C)	Max Temp (°C)	Min Temp (°C)	Rainfall (mm/day)	Relative Humidity (%)	Wind speed (m/s)	Solar Radiation($MJ/m^2/day$)
May	26.39	40.61	15.69	0.84	37.19	2.22	*26.32*
June	30.82	43.21	13.99	0.74	28.06	2.39	*27.03*
July	28.95	40.06	20.40	3.01	51.67	2.09	*24.96*
August	28.43	39.09	19.79	3.24	53.15	2.09	*23.68*
September	24.79	34.67	15.25	1.69	54.01	1.90	*21.85*

Source: NASA POWER (Prediction of Worldwide Energy Resources), MERRA-2 and CERES datasets, Batikot, Nangarhar, Afghanistan (Lat 34.29°N, Lon 70.76°E), 2025.

2.6 Data Collection

Data were collected from the inner rows of each plot to minimize border effects. The parameters measured in this experiment were: plant height(cm) was measured from the soil surface up to the top of the plant, stem diameter was measured using a digital caliper, leaf number per plant was recorded manually, while cob length was measured using a measuring tape in (cm), weight of 1000 grains was determined by counting 1000 grains and weighing them using digital balance, the number of grains per cob determined by counting grains manually, fresh cob yield, Biological weight, fresh net grain yield per cob and Grain weight per cob were recorded using a weighing balance and expressed in grams or kilograms as appropriate.

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2.7 Statistical Analysis

For statistical analysis, all collected data were processed in MS Excel. The collected data were subjected to analysis of variance (ANOVA) appropriate for a Randomized Complete Block Design (RCBD) to determine the effects of nitrogen treatments on the measured parameters. Statistical analysis was performed using STAR statistical software. Treatment means were separated using the Least Significant Difference (LSD) test at a significance level of $P \leq 0.05$.

3. RESULTS

The results presented below are based on the combined analysis of data collected from the two experimental locations (A and B). The effects of different nitrogen application rates on maize growth parameters are presented in Table 3. Four nitrogen treatments were evaluated 0, 130, 160 and 190 kg N ha^{-1}. Nitrogen application significantly affected plant height, number of leaves per plant, and stem diameter.

3.1 Growth Parameters

3.1.1 Plant height

Plant height increased significantly with increasing nitrogen fertilization rate. The control treatment (0 kg N ha^{-1}) produced the shortest plants, whereas the highest nitrogen rate (190 kg N ha^{-1}) resulted in the tallest plants. The application of 160 and 190 kg N ha^{-1} resulted in statistically similar, while 130 kg N ha^{-1} showed intermediate performance (Table 3).

3.1.2 Number of leaves per plant

The number of leaves per plant differed significantly among nitrogen treatments (Table 3). The lowest number of leaves was recorded in the control treatment (0 kg N ha^{-1}), while the highest number of leaves was recorded under 160 and 190 kg N ha^{-1}, which were statistically at par. The treatment receiving 130 kg N ha^{-1} showed an intermediate response.

3.1.3 Stem diameter

Stem diameter was significantly influenced by nitrogen application (Table 3). The smallest stem diameter was observed in the control treatment (0 kg N ha^{-1}), while the highest nitrogen rate (190 kg N ha^{-1}) produced the largest stem diameter. 160 kg N ha^{-1} resulted in a significantly greater stem diameter than 130 kg N ha^{-1}. The application of 190 kg N ha^{-1} was superior to all other treatments.

Table 3. Combined mean response of maize growth parameters to different nitrogen fertilization rates at physiological maturity stage (104 DAS) across two experimental locations (A and B), Batikot District, 2025.

Treatments	Plant height (cm)	Number of leaves	Stem diameter (cm)
T1 (0 kg N ha^{-1})	199 c	13.67 c	5.25 d
T2 (130 kg N ha^{-1})	217 bc	14.50 b	6.08 c
T3 (160 kg N ha^{-1})	224 ab	15.67 a	8.17 b
T4 (190 kg N ha^{-1})	244 a	15.83 a	9.92 a

3.2 Yield components

3.2.1 Number of grains per cob

The number of grains per cob is an important yield component that directly contributes to maize productivity. In the present study, different nitrogen levels resulted in significant differences in the number of grains per cob (Table 4). The highest number of grains per cob (455.00) was recorded with the application of 190 kg N ha^{-1}, followed by 160 kg N ha^{-1} (410.83) and 130 kg N ha^{-1} (339.17). The lowest number of grains per cob (280.00) was recorded in the control treatment (0 kg N ha^{-1}). The statistical analysis indicated significant differences among all nitrogen treatments.

3.2.2 Cob length

Cob length was significantly affected by nitrogen application (Table 4). The control treatment without nitrogen (0 kg N ha^{-1}) produced the shortest cobs (15.00 cm), followed by 130 kg N ha^{-1} (17.00 cm) and 160 kg N ha^{-1} (20.00 cm), while the longest cobs

(22.00 cm) were recorded with the application of 190 kg N ha⁻¹. The statistical analysis indicated significant differences among all nitrogen treatments.

3.2.3 Grain weight per cob

Different nitrogen rates significantly affected grain weight per cob (Table 4). Grain weight per cob increased progressively with increasing nitrogen application. The highest grain weight per cob (133.17 g) was recorded with the application of 190 kg N ha⁻¹, followed by 160 kg N ha⁻¹ (122.33 g) and 130 kg N ha⁻¹ (97.00 g), while the lowest grain weight per cob (88.67 g) was recorded in the control treatment (0 kg N ha⁻¹). The statistical analysis indicated significant differences among all nitrogen treatments.

3.2.4 1000- Grain weight

Similarly, 1000-grain weight was significantly affected by nitrogen application (Table 4). The highest 1000-grain weight (300.00 g) was recorded with the application of 190 kg N ha⁻¹, followed by 160 kg N ha⁻¹ (285.67 g) and 130 kg N ha⁻¹ (274.00 g), while the lowest 1000-grain weight (246.83 g) was recorded in the control treatment (0 kg N ha⁻¹). The statistical analysis indicated significant differences among all nitrogen treatments. This indicates that increased nitrogen application positively influenced grain development and increased grain weight.

Table 4. Combined mean response of maize yield components to different nitrogen fertilization rates at physiological maturity stage (104 DAS) across two experimental locations (A and B), Batikot District, 2025.

Treatments	Number of grains per cob	Cob length(cm)	Grain weight per cob(gr)	1000- Grain weight(gr)
T1 (0 kg ha-1)	280.00 d	15.00 d	88.67 d	246.83 d
T2 (130 kg ha-1)	339.17 c	17.00 c	97.00 c	274.00 c
T3 (160 kg ha-1)	410.83 b	20.00 b	122.33 b	285.67 b
T4 (190 kg ha-1)	455.00 a	22.00 a	133.17 a	300.00 a

3.3 Yield performance

3.3.1 Biological yield

Biological yield represents the total biomass produced by the maize plants. The application of 190 kg N ha⁻¹ resulted in the highest biological yield (808.00 g), followed by 160 kg N ha⁻¹ (617.00 g), 130 kg N ha⁻¹ (533.67 g), and the control treatment (0 kg N ha⁻¹), which recorded the lowest biological yield (446.17 g). According to the statistical analysis, all nitrogen treatments differed significantly from each other (Table 5).

3.3.2 Fresh cob yield

Fresh cob yield of maize was significantly influenced by nitrogen levels. The maximum fresh cob yield (8.33 kg) was recorded with the application of 190 kg N ha⁻¹, followed by 160 kg N ha⁻¹ (7.13 kg), 130 kg N ha⁻¹ (6.68 kg), and the control treatment (0 kg N ha⁻¹), which recorded the minimum fresh cob yield (5.08 kg). The statistical analysis showed significant differences among all nitrogen treatments (Table 5).

3.3.3 Fresh net grain yield per cob

Fresh net grain yield per cob of maize was significantly influenced by nitrogen levels. The highest fresh net grain yield per cob (153.17 g) was recorded with the application of 190 kg N ha⁻¹, followed by 160 kg N ha⁻¹ (138.83 g), 130 kg N ha⁻¹ (122.33 g), and the control treatment (0 kg N ha⁻¹), which recorded the lowest value (110.00 g). The statistical analysis indicated significant differences among all nitrogen treatments (Table 5). Overall, fresh net grain yield per cob increased progressively with increasing nitrogen application.

3.3.4 Grain yield

Grain yield of maize was significantly affected by different nitrogen levels (Table 5). The highest grain yield (9,255.55 kg ha⁻¹) was recorded with the application of 190 kg N ha⁻¹, followed by 160 kg N ha⁻¹ (7,922.22 kg ha⁻¹) and 130 kg N ha⁻¹ (7,422.22 kg ha⁻¹), while the lowest grain yield (5,644.44 kg ha⁻¹) was recorded in the control treatment (0 kg N ha⁻¹). The statistical analysis indicated

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significant differences among all nitrogen treatments. The increase in grain yield with increasing nitrogen application may be attributed to improved vegetative growth, increased grain number per cob, and higher grain weight.

Table 5. Combined mean response of maize yield performance to different nitrogen fertilization rates at physiological maturity stage (104 DAS) across two experimental locations (A and B), Batikot District, 2025.

Treatments	Biological yield (g)	Fresh cob yield (kg)	Fresh net grain yield per cob(g)	Grain yield (kg ha^{-1})
T1 (0 kg N ha^{-1})	446.17 d	5.08 d	110.00 d	5644.44 d
T2 (130 kg N ha^{-1})	533.67 c	6.68 c	122.33 c	7422.22 c
T3 (160 kg N ha^{-1})	617.00 b	7.13 b	138.83 b	7922.22 b
T4 (190 kg N ha^{-1})	808.00 a	8.33 a	153.17 a	9255.55 a

3.4 Relationship between nitrogen application and maize grain yield

Regression analysis showed a positive relationship between nitrogen application rates and maize grain yield. Grain yield increased with increasing nitrogen rates from 0 to 190 kg N ha^{-1}, indicating that nitrogen application positively influenced maize productivity. A regression equation and coefficient of determination (R^2) were used to describe the relationship between nitrogen rate and grain yield

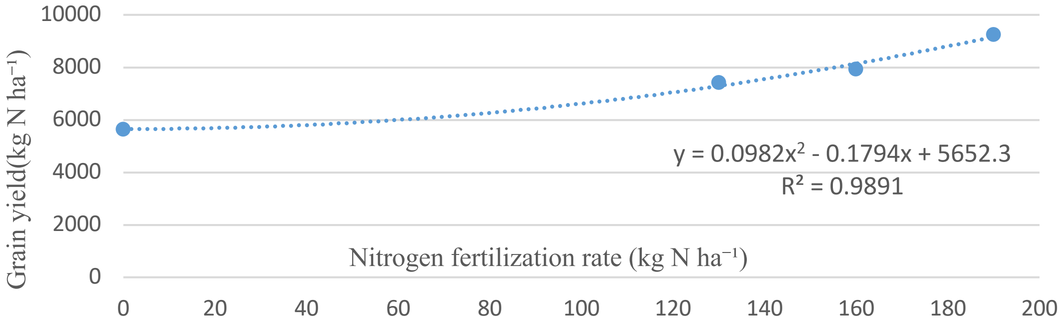

Figure 1. Quadratic regression showing the relationship between nitrogen fertilization rate and grain yield of hybrid maize.

Table 6: Correlation coefficients among growth and yield parameters of hybrid maize under different nitrogen rates.

Variable Pair	*Correlation coefficient(r)*	*Interpretation*
Nitrogen Rate vs. Plant Height	+0.98 (strong positive)	Higher nitrogen → taller plants
Nitrogen Rate vs. Grain Number/Cob	+0.99 (very strong)	More nitrogen → more grain
Nitrogen Rate vs. Grain Yield	+0.97(strong positive)	More nitrogen → higher yield

3.5 Nitrogen Use Efficiency (NUE)

Agronomic nitrogen use efficiency (ANUE) was significantly influenced by nitrogen fertilization rates. The highest ANUE (19.01 kg grain kg^{-1} N) was recorded at 190 kg N ha^{-1}, followed by 160 kg N ha^{-1} (14.24 kg grain kg^{-1} N) and 130 kg N ha^{-1} (13.67 kg grain kg^{-1} N). This indicates that increasing nitrogen application improved the efficiency of nitrogen utilization under the experimental conditions.

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Agronomic nitrogen use efficiency (ANUE) was calculated using the following equation:

$$ANUE = (Y_n - Y_0) / N_a$$

Where Y_n is the grain yield under nitrogen application, Y_0 is the grain yield of the control treatment (0 kg N ha⁻¹), and N_a is the amount of applied nitrogen (kg ha⁻¹).

Table 7. Agronomic nitrogen use efficiency of hybrid maize under different nitrogen rates.

Treatments	N rate (kg ha^{-1})	Grain yield (kg ha^{-1})	NUE (kg grain kg^{-1} N)
T1	0kg N ha^{-1}	5644.44	-
T2	130 kg N ha^{-1}	7422.22	13.67
T3	160 kg N ha^{-1}	7922.22	14.24
T4	190 kg N ha^{-1}	9255.55	19.01

3.6 Economic optimum nitrogen dose

Economic analysis showed that the application of 190 kg N ha^{-1} produced the highest grain yield and maximum net return compared with the other nitrogen fertilization rates. Therefore, 190 kg N ha^{-1} was identified as the economic optimum nitrogen rate for hybrid maize production under the agro-climatic conditions of Nangarhar Province, Afghanistan.

Table 8. Economic performance and optimum nitrogen rate for hybrid maize production under different nitrogen levels.

Treatments	N rate (kg ha^{-1})	Urea applied (kg ha^{-1})	Grain yield (kg ha^{-1})	Gross return (AFN ha^{-1})	Urea cost (AFN ha^{-1})	Net return (AFN ha^{-1})
T1	0kg N ha^{-1}	0	5644.44	161270	0	161270
T2	130 kg N ha^{-1}	282.61	7422.22	212063	8075	203988
T3	160 kg N ha^{-1}	347.83	7922.22	226349	9940	216409
T4	190 kg N ha^{-1}	413.04	9255.55	264444	11801	252643

Note: Grain price was 200 AFN per 7 kg grain (28.57 AFN kg^{-1}), and urea price was 1400 AFN per 49 kg urea (28.57 AFN kg^{-1}).

4. DISCUSSIONS

Nitrogen fertilizer application significantly influenced the maize growth, yield components and yield performance under the agro-climatic conditions of Batikot district, Nangarhar Province, Afghanistan. The positive response of maize to increasing nitrogen rates may be attributed to improved nitrogen availability, which enhances chlorophyll formation, photosynthetic activity, protein synthesis, and dry matter accumulation. Adequate nitrogen supply promotes vegetative growth, improves leaf development, and increases assimilate production, ultimately contributing to higher yield formation.

4.1 Effect of nitrogen on growth parameters

Nitrogen application significantly increased maize plant height due to improved vegetative growth and enhanced physiological processes. Adequate nitrogen availability stimulates chlorophyll synthesis, cell division, and cell elongation, resulting in greater plant growth. Similar responses were reported by (Bakht et al., 2006) and (Keskin et al., 2005), who observed increased maize plant height with higher nitrogen application rates.

Stem development was improved with increasing nitrogen levels, which may be attributed to enhanced biomass accumulation and cell development. Similar findings were reported by Iqbal et al. (2015) and Wang et al. (2020), who observed improved stem characteristics with increased nitrogen application in maize.

Higher nitrogen availability increased the number of leaves per plant by promoting leaf initiation and expansion. Nitrogen plays an important role in chlorophyll formation and photosynthetic activity, which enhances vegetative growth and increases leaf area. Similar findings were reported by Gungula et al. (2005) and Adhikari et al. (2021), who observed improved vegetative growth with increasing nitrogen application in maize.

4.2 Effect of nitrogen on yield components

Nitrogen application improved maize yield components, including cob length, grain number per cob, grain weight per cob, and 1000-grain weight. The improvement in cob development with increasing nitrogen levels may be related to enhanced nutrient availability during reproductive growth, which increases assimilate supply and supports better ear formation. Similar findings were reported by Adhikari et al. (2021) and Abebe et al. (2021), who reported that increasing nitrogen application significantly improved cob length in maize.

The increase in grains per cob with higher nitrogen levels may be attributed to improved photosynthetic capacity, better pollination, and increased assimilate availability during grain formation. Similar findings were reported by Valero et al. (2005) and Bawa. (2021), who observed that increasing nitrogen application increased the number of grains per ear and grain yield in maize.

The increase in grain weight per cob with higher nitrogen levels may be attributed to improved photosynthetic activity, enhanced assimilate translocation, and better grain filling during the reproductive stage. Similar findings were reported by El-Hosary et al. (2022) and Stesi et al. (2020), who observed that increasing nitrogen application significantly increased grain weight per cob in maize.

Higher nitrogen rates also increased 1000-grain weight. This improvement may result from enhanced grain filling due to increased photosynthesis and efficient translocation of carbohydrates from source tissues to developing grains. Similar findings were reported by Khalili et al. (2018) and Rahman et al. (2016), who observed improved grain weight with increasing nitrogen application.

4.3 Effect of nitrogen on yield performance

Nitrogen application significantly increased biological yield of maize. The higher biological yield under increased nitrogen levels may be attributed to enhanced vegetative growth, greater leaf area development, improved photosynthetic activity, and increased dry matter accumulation. Similar findings were reported by Majid et al. (2017) and Wasaya et al. (2017), who observed that higher nitrogen application increased biomass production in maize.

The increase in fresh cob yield under higher nitrogen levels may be attributed to improved vegetative growth, greater assimilate production, and enhanced development of yield components. Similar findings were reported by Bhatnagar et al. (2019) and Abhishek & Basavanneppa. (2020), who observed that increasing nitrogen application significantly increased fresh cob yield and other yield attributes of maize.

Nitrogen application increased fresh net grain yield per cob due to improved assimilate production, better grain filling, and enhanced development of yield components. Similar findings were reported by Madagoudra et al. (2021) and Agnieszka Tomkowiak et al. (2019), who observed that increasing nitrogen application significantly increased grain weight per cob in maize.

Overall, the results indicate that adequate nitrogen nutrition improves both source capacity (photosynthetic activity and biomass production) and sink development (grain formation and filling), resulting in increased maize productivity. The highest nitrogen rate (190 kg N ha^{-1}) showed the best performance under the environmental conditions of Batikot District.

5. CONCLUSION

Nitrogen application had a notable effect on the growth and yield of hybrid maize. Overall, growth and yield parameters increased with increasing nitrogen rates from 0 to 190 kg N ha^{-1} under the agro-climatic conditions of Nangarhar, Afghanistan. The application of 190 kg N ha^{-1}, applied in three split doses (¼ at sowing, ½ at the knee-height stage, and ¼ at the tasseling stage), produced the highest growth and yield performance and provided the highest economic return under the experimental conditions. Therefore, 190 kg N ha^{-1} can be recommended for hybrid maize production under similar agro-climatic conditions.

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