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RESEARCH

Effect of Different Doses of Nitrogen on Growth and Grain Yield of Hybrid Maize (*Zea mays* L., Gold 97)

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Abstract

This study investigates the impact of various nitrogen doses on the growth and grain yield of hybrid maize (*Zea mays* L., Gold 97). Nitrogen plays an important role in crop phenology, morphology, and grain yield of maize plants. A field experiment was conducted in a randomized complete block design with six levels of nitrogen (150, 160, 170, 180, 190, and 200 kg/ha) in four replications to evaluate the effect of different doses of nitrogen on the growth and yield of maize. Germination percentage, Days to 75% tasselling and silking, plant height, number of leaves, leaf area (LAI), cobs length, grain per row, pod, and total grain yield were recorded. Maximum germination was found in 180 kg N /ha. Plant height, number of leaves, and leaf area (LAI) were found to be maximum in the plots treated with 180-200 kg/ha of N. This field experiment revealed that different nitrogen dose has significant effects on days to 75% Tasselling and silking and found to be maximum in 180 kg/ha N treated plot. Also, nitrogen has a significant effect on cobs length, and grain per row was found highest at 180 kg N/ha. The highest Grain yield was found 180 kg/ha N treated plot. Findings have demonstrated that increasing nitrogen levels can often lead to increased grain yield up to a certain point, after which the yield plateaus or even declines. These findings provide valuable guidance for optimizing agricultural practices to meet the increasing global demand for cereal crops.

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Statement of Sustainability: This research mainly aims to promote the Sustainable Development Goals by considering key issues related to sustainability in cereal crop production. Increasing the yield performance of maize by choosing the appropriate nitrogen dose contributes to achieving SDG 1(No Poverty). This research also supports the second Goal of SDG 2 (Zero Hunger). Also, the research is intended to minimize the negative environmental impacts of excessive nitrogen use and support biodiversity conservation. It aims to achieve SDG Goal 12 (Responsible consumption and production) and SDG Goal 15 (Life on Land).

1. Introduction

Maize (*Zea mays* L.) belongs to the family Poaceae grown in the summer season in both irrigated and rain-fed areas (Ullah et al., 2023a). Maize can adapt wide range of environments having the highest production potential hence called as 'Queen of Cereals' (Begam et al., 2018; Singh et al., 2021). The global demand for maize has been increasing and in the next two decades, it may rise by 4% to 6% per year as the livestock and poultry industries expand (Bk et al., 2018). The total area, production, and productivity of maize were 940886 ha, 2643243 metric tons, and 2.82 MT/ha respectively (Adhikari et al., 2021). Cultivation of hybrid maize is increasing, and the hilly region of Nepal has covered almost 50% of the maize areas with hybrid maize (Timsina et al., 2016). The average grain yield of maize is 2 T/ha with an exploitable gap of 4.5 tons/ha where better agronomic practices improve yield to 6.5 tons/ha (Dhakal et al., 2022). Due to its high nutrient utilization capability maize is a plant that requires a lot of nutrients. Nitrogen has a critical role in crop phenology and is considered the most important Macronutrient in determining yield and yield parameters of maize (Sharifi and Namvar, 2016). The nitrogen requirement of maize at different stages can be determined by using physiological components such as interception and effective use of radiation as well as nitrogen partitioning in reproductive organs (Sandhu et al., 2021). Application of nitrogen fertilizer has increased global maize production, in the past four decades (Su et al., 2020). Maize is the third most cultivated crop for staple food in the world (Adhikari et al., 2021). Nitrogen is a mandatory element and is provided as a nitrogen (N) fertilizer. The maize yield increase in nitrogen fertilizer application rates and N fertilizer has a significant effect on nitrogen uptake at different maize growth stages: tasseling, grain filling, and maturity (Nduwimana, 2020). The response of maize plants to nitrogen fertilizer treatment varies from variety to variety, location to location, and also relies on nutritional availability (Onasanya et al., 2009). The average application of nitrogen fertilizer by the farmer was 300 kg/ha which was far more away from the average requirement for the maize production (Yang et al., 2021). More than 50% of the nitrogen fertilizers applied are not utilized by the plants because of leaching out into the groundwater (Modolo et al., 2018). So, a comprehensive study on nitrogen fertilizer management in maize is very crucial. To avoid excessive use of nitrogen, loss of the environment, and improvement of maize productivity a better understanding of nitrogen acquisition and mobilization is vital (Aziiba et al., 2019). According to the research done by Sharma et al. (2018), the plant can use only 33% of the nitrogen applied in agricultural fields so, for the improvement of nitrogen use efficiency (NUE) nitrogen management tools and methods should be implicated wisely and scientifically. Implementation of 180 kg N /ha of nitrogen has higher plant growth with higher grain yield of the maize. Application of more than the required amount not only increases the cost of production it also increases the leaching loss of nutrients, resulting in environmental pollution (Zhao et al., 2023). Combined application of organic and inorganic nitrogen fertilizers improves crop yields; as the long-term detrimental effect of nitrogen application in maize fields has not been reported yet (Zhou et al., 2023). The highest yield of maize with dry matter weight and leaf nitrogen content was found in 270-360 kg N /ha, which was the highest nitrogen level (Zhao et al., 2023). Application at the rate of 250 kg N /ha is the best selection to increase the grain yield and improve the nitrogen use efficiency of maize (Li et al., 2023; Hu et al., 2023).

Application of top-dressing nitrogen fertilizer has a significant effect than other traditional methods of application (Żarski and Kuśmierek-Tomaszewska, 2023). A combination of a medium dose of biochar with different doses of nitrogen under the DI method would be the best nitrogen management practice to increase productivity and also to enrich soil organic matter (Wang et al., 2023a). Selecting an appropriate dose of nitrogen improves the grain yield of maize along with the quality of silage attributes as it increases the nitrogen ratio and decreases the ADF and NDF ratio of the silage sample (Uzun et al., 2020). Research conducted by Tanko and Momohjimoh (2022) suggests that the application of nitrogen fertilizer at two split doses was highly recommended for obtaining the optimum grain yield of the maize. 131.5 kg N/ha was found to be the best selection for the highest maize grain yield of 4.8 t/ha under the shade of coconut trees (Sution et al., 2021). The application of nitrogen fertilizer has a positive and significant effect on the number of ears per plant and weight of ears (Hammad et al., 2022). The use of nitrogen fertilizers at a rate of (150-190) kg/ha boosted green yields and yield-related features, such as the number of cobs per ha and thousand-grain weight in hybrid maize (Sharma et al., 2019). The application of nitrogen in three split doses as a basal dose during planting and knee-high stage and flowering improves maize production (Shrestha et al., 2018). Adhikari et al. (2021) researched to determine the effect of different doses of nitrogen on maize and suggested that the application of 220 kg N/ha gives the highest grain yield, cobs length, and leaf area.

Starvation of nitrogen resulted in a delay in attaining 50% tasseling and silking but speeding up the maturity period and 115 kg N /ha was the best recommendation (Begizew and Desalegn, 2019). As the level of nitrogen increases the 50 % tasseling, silking days, grains per cob, and grain yield increase linearly (Asif et al., 2013). Qualitative Characteristics of maize such as grain yield, and protein content are greatly influenced by nitrogen fertilizer (Dhital et al., 2022). Nitrogen-deficient can affect maize from the stage of anthesis to harvest because it plays a role in leaf longevity, greenness, chlorophyll content, and photosynthetic changes which are closely related to the grain yield of the maize (Li et al., 2020). Thus, this study was carried out in Gauradaha, Jhapan Nepal to assess the present scenario and existing problems in maize cultivation regarding nitrogen fertilizer management. This study will help to find the appropriate doses of nitrogen fertilizer for maize crop production.

2. Material and Methods

2.1. Study Area and Agroclimatic Condition

This study was carried out at IAAS, Gauradaha Agriculture Campus Research field in Gauradha-2, Jhapa, Nepal. This research was conducted in the winter season from January to April 2023. The research site had a climate with high temperatures and warm humidity. Its research field lies at 26° 33' N, 87° 43' E, and 114 masl. During the research time, there was an average rainfall of 50 -70 mm rainfall. Here, 40°C and 35°C were the maximum and minimum temperatures experienced during the research time. During the summer season maize experienced heat stress so for the fulfilment of water requirements, we applied furrow irrigation once a week.

2.2. Experimental Design and Treatment Details

The experiment was carried out in a Complete Randomized Block Design (RCBD). Six nitrogen treatments were taken and replicated four times each. There were altogether 24 plots having 3×2 m dimensions. In this research, the Gold 97 variety of maize was used. The treatment used in this experiment were T1 (150 kg N/ha), T2 (160 kg N/ha), T3 (170 kg N/ha), T4 (180 kg N/ha), T5 (190 kg N/ha) and T6 (200 kg N/ha).

2.3. Land Preparation and Agronomic Practices

Initially, the residue of the previous crop was removed by plowing with a power tiller up to a depth of 6 to 7 cm, followed by the breaking of the clod, and then leveling was done manually with the help of a spade. Organic manure (10 t/ha) was applied. DAP and Mop were applied at the rate of 60 kg/ha and 40 kg/ha respectively. The seed was sown at the rate of 25 kg/ha on 6th January of 2023, with 72×25 cm row-row and plant-plant spacing. Seeds were planted to a depth of 3-4 cm. Furrow irrigation was done in the field according to crop requirements via garden pipe and halted before the silking stage. Earthing up was done at 69 DAS with the side dressing of the 1st split dose of nitrogen. Emamectin benzoate (@5 g/16 L water) and Chlorpyriphos 50% + Cypermethrin 5% EC (2 mL/L water) were sprayed to reduce the infestation of Fall Army Worm (*Spodoptera frugiperda*). Manual harvesting was done. Harvesting was done when the black mark was on the bottom (side attached to the cob) of the seed. Manual harvesting was done by plucking the ears off the plant stalk.

2.4. Observation of Crop Parameter

Required plant densities were maintained and eight randomly selected plants per plot were observed for various parameters. Germination percentage was calculated by observing the plant germinated in the field. It was calculated using the given formula:

$$\text{Germination \%} = (\text{Total sprouted seedlings}/\text{Total seeds}) \times 100$$

The Leaf Area Index (LAI) was determined by using the formula (Ahmad et al., 2024):

$$\text{LAI} = (\text{Leaf area plant} - 1 \,/\, \text{Ground area})$$

Plant height, number of leaves per plant, and leaf area were measured five times from 30 DAS fortnightly up to 90 DAS and the average was calculated. The days to 75% Tasselling and the days to 75% silking were measured by observing from the respective plots. Similarly, the number of grains per row, and cobs length was measured. After manual harvesting and drying total grain yield was calculated.

2.5. Statistical Analysis and Interpretation of Data

The data entry was done in Microsoft Excel (Version 2019, Microsoft Corp., USA). These data were subjected to statistical analysis using SPSS version 2017. For the determination of significant differences between data points analysis of variance (ANOVA) was used and for comparison, Duncan's Multiple Range Test (DMRT) was used.

3. Result and Discussion

3.1. Germination Percentage

The application of different doses of nitrogen has a significant role in the germination of maize (Table 1). The Number of normal seedlings was observed after a 10-day. The highest germination percentage was observed in treatment T4 (98.32%) followed by treatment T5 (97.11%) which was statistically at par with treatment T6 (96.42%), and T3 (95.53%). The lowest germination percentage was found in treatment T1 (91.07%). A similar result was found by Owais et al. (2023), where the maximum germination (90%) was found in a 180 kg/ha nitrogen-treated plot. This result is also supported by the finding of Deng et al. (2023), where they found that the highest percentage of germination was found in plots treated with 180-200 kg/ha of nitrogen dose. Szabó et al. (2022) also found that nitrogen has a significant effect on the days of emergence by improving nutrient conditions for the germination of maize. Nitrogen is irreplaceable and has significantly impacted the growth and yield-related traits of maize and 150-200 kg N/ha is optimum (Ahmad et al., 2024).

Table 1. Effect of different doses of nitrogen on germination of maize

Treatments	Germination (%)
T1	91.07a
T2	92.85ab
T3	95.53bc
T4	98.32c
T5	97.11c
T6	96.42bc
Grand Mean	95.22
F-value	*
LSD	1.56
CV%	3.74

Note: C.V.: Coefficient of Variation, LSD: Least Significant Difference, (*): Significant at 5% level of significance, NS: non-significant

3.2. Effect of Nitrogen Doses on Silking and Tasseling Days

Table 2 represents the effect of different doses of nitrogen on 75% Tasseling and Silking days of the maize. It was observed that early tasseling was observed in treatment T4 (80.625 ±0.33days) and T5 (81.815 ±0.91 days) respectively followed by T3 (82.408 ±0.75 days). In the case of silking earlier silking was found in treatment T4 (85.387±0.15 days) followed by T5 (86.346±0.19 days). This result followed the finding of Okab and Abed (2022), where the earliest tasseling and silking days were seen in the plot treated with (100-200) N kg/ha treated plot. This finding agrees with the finding of Singh et al. (2021), where early tasseling and silking days were seen in treatment with 100kg N/ha. This result also agrees with the finding of Shrestha et al. (2018), where early tasseling days (47.00 days) and silking (52.22 days) were found in the highest nitrogen level. Begizew and Desalegn, (2019) found that the rate of nitrogen application has a direct effect on days of tasseling and days of silking on maize.

Table 2. Effect of different doses of nitrogen on 75% tasseling days, 75% silking days, cobs length, and grain per row of maize.

Treatments	Tasseling Days	Silking Days	Cobs Length (cm)	Gains/Row
T1	82.532b ±0.52	85.937ab ±0.50	17.635ab±0.38	13.782a
T2	82.908b ±0.19	86.690bc±0.60	16.825a±0.20	14.062ab
T3	82.408b ±0.75	86.432abc±0.13	17.585ab±0.37	13.937ab
T4	80.625a ±0.33	85.387a±0.15	18.776bc±0.39	15.000d
T5	81.815a ±0.91	86.346abc±0.19	18.498bc±0.63	14.687cd
T6	83.502b ±0.40	87.377c±0.18	19.066c±0.29	14.312bc
Grand Mean	82.298	86.361	18.063	14.297
F-value	*	*	*	*
LSD	1.6	1.08	1.28	1.42
MS-error	1.13	0.51	0.72	1.02
CV%	1.29	0.83	4.72	3.502

Note: C.V.: Coefficient of Variation, LSD: Least Significant Difference, (*): Significant at 5% level of significance, NS: insignificant, Ms error: Mean square error.

3.3. Effect of Nitrogen on Cob Lengths

The highest cob length (19.066±0.29 cm) was found in the T6 treatment followed by treatment T4 (18.776±0.39 cm) and T5 (18.498±0.63 cm) which are statistically at par. The lowest cob length was found in the T2 treatment (16.825±0.20 cm). A similar result was found by Bakry et al. (2023), where maximum cob length (22.12 ± 0.17 and 23.02 ± 0.18 cm) was found with the increase in nitrogen level. This result was in accordance with the finding of Lakshmi et al. (2020), where the highest cob length (23.4 cm) was found in a 200 kg/ha nitrogen-treated plot followed by 160 kg N/ha. This result was also supported by the findings of Dhital et al. (2022), where the highest cob length was found in (140-200) kg N/ha treated plots. A similar result was also reported by Kumar et al. (2018), where the highest cob length (15.05 cm) at the recommended RDF of nitrogen. Higher nitrogen enhances the cell division and expansion so it may be the reason behind the increased length of the cob. This result also agreed with the findings of K.C et al. (2021), where the longest cob length (15.16 cm) was measured for 120 kg N/ ha.

3.4. Effect of Nitrogen on Grain Per Row

Under field conditions, the effects of the tested treatments were evaluated. Table 2 demonstrates that the higher the amount of nitrogen dose significantly higher the grain per row. Maximum grain per row was found in treatment T4 (15 grain/row) followed by T5 (14.687 grain/row). Plot treated with 150 kg N /ha had the lowest T1 (13.782 grain per row) grain per cob. This result was supported by the findings of Karki et al. (2020), where nitrogen has a direct effect on the kernel per row of the maize. A similar result was found by Kapela et al. (2020) where 120-180 kg N/ha had the highest grain per cob while the doses of 160 kg N /ha had the best effect on the highest mass value of thousand-grain seeds. This result also follows the findings of Jyosthna et al. (2023), who revealed that an enhanced dose of nitrogen (125%) gave the grain per row (37.0 grain/row) of the cobs. K.C et al. (2021) also found a similar result i.e., 24.6 grain per row was found in higher levels of nitrogen dose. Higher grain per row may be the result of lower competition for the accumulation of biomass in higher doses of nitrogen.

3.5. Effect of Nitrogen on Plant Height

Plant height is the main growth trait of plants, which is affected by the genetic makeup of the cultivar or related to the fertility status of the soil. Nitrogen doses significantly influenced the plant height at different growth stages (Table 3). There was no significant difference observed in plant height at 30 and 45 DAS but, significant effects of different doses of nitrogen on plant height were observed at 60, 75, and 90 DAS. At 60 DAS, the highest plant height was seen in T4 (32.055±0.55 cm), and the lowest plant height was seen in T6 (26.469±1.02 cm). At 75DAS, the highest plant height was observed in T4 (65.30±1.6 cm), and the lowest plant height was seen in T3 (54.50±2.03 cm). At 90 DAS, the highest plant height was observed in T4 (150.766±22.2 cm), and the lowest plant height was observed in T1 (108.767±4.86 cm). These results are in agreement with findings by (Adhikari et al., 2021). This result is supported by the findings of Mahmood et al. (2001), where the maximum plant height (228.2cm) was found in the plot treated with 180 kg N/ha. These results are in agreement with the findings of Sabagh et al. (2017), who observed that maximum plant height (269.3 cm) was achieved with 345 kg N/ha. These results are also in agreement with the findings of Ullah et al. (2023) and Tirfi (2023), who found the highest plant height (196 cm) on a 180-210 kg N/ha treated plot. A similar result was found by Karki et al. (2020), where the maximum height (140.40 cm) of the plant was found in the plot treated with 120 kg N/ha. A similar result was registered by Singh et al. (2021), at higher doses highest plant height (216.0 cm) was observed.

Table 3. Effect of different doses of nitrogen on plant height.

Treatments	30 DAS (cm)	45 DAS (cm)	60 DAS (cm)	75 DAS (cm)	90 DAS (cm)
T1	10.68a±0.59	15.70a±0.60	27.030a±1.45	55.027a±1.74	108.767a±4.86
T2	11.81a±0.54	16.26a±0.8	28.197a±0.58	60.40ab±3.03	115.417a±4.64
T3	10.79a±0.81	15.47a±0.95	26.765a±0.57	54.50a±2.03	100.90a±2.34
T4	11.65a±0.24	15.28a±0.96	32.055b±0.55	65.30b±1.6	150.766b±22.2
T5	11.77a±0.65	15.17a±0.77	27.803a±1.88	61.320ab±2.80	124.706ab±7.63
T6	10.31a±0.60	14.59a±0.57	26.469a±1.02	59.678ab±2.10	110.055a±3.25
Grand Mean	11.16	15.41	28.05	59.37	118.43
F-value	NS	NS	*	*	*
LSD	1.894	2.57	3.59	6.67	30.69
MS error	1.58	2.91	5.7	19.61	414.8
CV%	11.25	11.06	8.51	7.45	17.19

Note: C.V: Coefficient of Variation, LSD: Least Significant Difference, (*): Significant at 5% level of significance, NS: non-significant; Ms error: Mean square error.

3.6. Effect of Nitrogen on Number of Leaves

The number of leaves/plants of maize was significantly influenced by the nitrogen levels at different dates of observation. Table 4 presented the effects of nitrogen doses on leaf numbers indicating that significantly affected 60, 75, and 90 DAS. There were no significant differences in no. of leaves at 30 and 45 DAS. However, at 60 DAS the highest leaf number was observed in T4 (9.918±0.68 /plant), and the lowest leaf number was observed in T1 (8.127±0.44 /plant). At 75 DAS the highest leaf number was observed in T4 (9.345±0.23 /plant) and the lowest leaf number was observed in T5 (8.220±0.12 /plant). At 90 DAS the highest leaf number was observed in T4 (10.440±0.17 /plant) and the lowest leaf number was observed in T3 (9.937±0.23 /plant). This result was supported by the findings of Hammad et al. (2022), who found that the application of nitrogen is good for increasing the number of leaves per plant because the application of nitrogen increases the length of nodes and internodes. This result is also supported by the field experiment conducted by Amanullah et al. (2009), where the highest number of leaves was found in a 180 kg/ha N treated plot. Similar results were registered by Haraga and Ion (2023), where the maximum leaf number was found in higher nitrogen doses. Shrestha (2015) uncovered that nitrogen directs the multiplication and elongation of leaves and ultimately increases the number of leaves per plant.

Table 4. Effect of different doses of nitrogen on no. of leaves in maize.

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90DAS
T1	4.752a±0.13	6.657a±0.18	8.127a±0.44	8.752ab±0.05	10.285bc±0.15
T2	4.907a±0.06	6.595a±0.09	8.375a±0.46	8.845bc±0.13	10.282bc±0.12
T3	4.940a±0.15	6.417a±0.11	8.472ab±0.13	8.282ab±0.25	9.937a±0.23
T4	4.718a±0.07	7.815a±1.53	9.918c±0.68	9.345c±0.23	10.440c±0.17
T5	4.876a±0.08	6.375a±0.13	9.716bc±0.28	8.220a±0.12	10.327bc±0.14
T6	4.781a±0.19	6.315a±0.08	8.813abc±0.15	8.315ab±0.19	10.085ab±0.18
Grand Mean	4.82	6.695	8.9	8.626	10.226
F-value	NS	NS	*	*	*
LSD	0.37	1.88	1.24	0.54	0.3
Ms error	0.06	1.57	0.68	0.13	0.04
CV	5.091	18.71	9.26	4.21	2

Note: C.V.: Coefficient of Variation, LSD: Least Significant Difference, (*): Significant at 5% level of significance, NS: non-significant; Ms error: Mean square error.

3.7. Effect of Nitrogen on Leaf Area

There are no significant differences in LAI at 30 and 45 DAS to leaves area but after 60DAS, the significantly highest leaf area was found in T4 (234.922±28.9 cm^2), and the lowest leaf area was observed in T3 (121.545±8.56 cm^2). At 75DAS the highest leaf area was found in T4 (466.341±16.2 cm^2) and the lowest leaf area was observed in T1 (388.270±41.5 cm^2). At 90DAS the highest leaf area was observed in T4 (615.971±21.7 cm^2) while the lowest leaf area was observed in treatment T2 (491.864±30.6 cm^2). This finding aligns with the finding of Wu et al. (2022). Also, the study done by Yadav et al. (2022) shows that nitrogen plays a vital role in LAI of the plants. Availability of paramount N is for optimum LAI of the maize plant (Raniro et al., 2023).

Table 5. Effect of nitrogen on leaf area in maize.

Treatments	30DAS (cm^2)	45DAS (cm^2)	60DAS (cm^2)	75DAS (cm^2)	90DAS (cm^2)
T1	27.450a±0.64	43.495a±2.22	144.040a±7.15	388.270ab±41.5	530.745abc±33.4
T2	28.477a±2.23	46.850b±4.51	142.117a±13.0	438.590bc±20.6	491.864a ±30.6
T3	26.000a±1.23	44.560ab±2.86	121.545a±8.56	359.942a±24.8	527.360ab ±26.7
T4	27.416a±2.95	51.847ab±1.98	234.922b±28.9	466.341c±16.2	615.971c ±21.7
T5	26.958a±1.81	37.667a±0.90	137.636a±23.1	442.843bc±23.5	581.482bc ±34.3
T6	26.506a±1.14	43.769ab±4.22	149.867a±13.6	414.953abc±12.6	579.558bc ±9.29
Grand Mean	27.129	44.698	155.021	418.49	554.496
F value	NS	NS	*	*	*
LSD	4.78	8.06	53.52	66.89	79.26
Ms-error	10.06	28.65	126 1	1970	2766
CV%	11.69	11.97	22.9	10.6	9.48

Note: C.V.: Coefficient of Variation, LSD: Least Significant Difference, (*): Significant at 5% level of significance, NS: non-significant; Ms error: Mean square error, Figure after ± indicate Standard Error.

3.8. Effect of Nitrogen on Grain Yield

Table 6 depicted that the highest yield (8.365 MT/ha) was found in Treatment T4 followed by Treatment T6 (7.960 MT/ha), and the lowest yield (6.435 MT/ha) was found in Treatment T3. A similar result was found by Hammad et al. (2018), where the highest yield of maize was found by increasing the nitrogen concentration during the early stage. This result is in accordance with the finding of Wang et al. (2023b), where the highest yield of 17.1-23.0 t/ha of maize was found in the plot treated with N of 156-213 kg/ha. This result is also supported by the findings of Chen et al. (2023), where the maximum yield was found in (120.6–170.0 kg N/ha). A similar result was obtained by Nasar et al. (2023) in the field experiment conducted in 2021 and 2022 where a 30-34% increase in grain yield was obtained by the application of 250 kg N/ha.

Research done by Li et al. (2023) noted that a nitrogen dose of up to 250 kg/ha is the best choice to increase grain yield and above this limit nitrogen use efficiency (NUE) will decrease gradually. These findings align with existing literature highlighting the importance of nitrogen in promoting early reproductive stages and improving yield-related traits in maize

Table 6. Effect of different doses of nitrogen on grain yield of maize.

Treatments	Grain Yield (MT/ha)
T1	6.687a
T2	6.950ab
T3	6.435a
T4	8.365c
T5	7.047ab
T6	7.960bc
Grand Mean	7.24
F-value	*
LSD	1.96
CV	12.428

Note: C.V.: Coefficient of Variation, LSD: Least Significant Difference, (*): Significant at 5% level of significance, NS: non-significant.

4. Conclusion

Different levels of N have significantly affected the yield and yield components of maize. Different doses of nitrogen had a substantial impact on germination with the highest germination observed in treatment T4 followed closely by T5. The study has demonstrated a significant increase in grain yield with the application of nitrogen, with treatment T4 (180 kg N/ha) yielding the highest grain.

These results corroborate previous research indicating the positive impact of nitrogen fertilization on maize productivity. Nitrogen doses exerted a significant effect on plant height throughout different growth stages. The findings of this study highlight the critical role of nitrogen in optimizing various growth and yield parameters of maize. The selection of a suitable hybrid and understanding the effects of nitrogen application can aid farmers in implementing efficient fertilizer management practices to maximize crop productivity and ensure food security. Further research into optimizing nitrogen application rates and timing could provide valuable insights for sustainable maize production in agricultural systems.

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References

Adhikari, K., Bhandari, S., Aryal, K., Mahato, M., & Shrestha, J. (2021). Effect of different levels of nitrogen on growth and yield of hybrid maize (*Zea mays* L.) varieties. *Journal of Agriculture and Natural Resources*, 4(2), 48–62. https://doi.org/10.3126/janr.v4i2.33656

Ahmad, H., Ahmed, U., Ullah, I., & Masud, H. (2024). Comparing Fodder Production of Maize Varieties Under Varied Nitrogen Levels. *Journal of Applied Life Sciences and Environment*, 56(4), 551–562. https://doi.org/10.46909/alse-564116

Amanullah, Khattak, R. A., & Khalil, S. K. (2009). Plant Density and Nitrogen Effects on Maize Phenology and Grain Yield. *Journal of Plant Nutrition*, 32(2), 246–260. https://doi.org/10.1080/01904160802592714

Asif, M., Saleem, M. F., Anjum, S. A., Wahid, M. A., & Bilal, M. F. (2013). Effect of nitrogen and zinc sulphate on growth and yield of maize (*Zea mays* L.). *Journal of Agricultural Research*, 51(4), 445.

Aziiba, E. A., Qiang, C., & Coulter, J. A. (2019). Mechanisms of nitrogen use in maize. *Agronomy*, 9(12), 775. https://doi.org/10.3390/agronomy9120775

Bakry, M. M. S., Maharani, Y., & Al-Hoshani, N. (2023). Influence of maize planting methods and nitrogen fertilization rates on mealybug infestations, growth characteristics and eventual yield of maize. *International Journal of Agriculture and Biology*, 29(6), 401–409.

Begam, A., Ray, M., Roy, D. C., & Adhikary, S. (2018). Performance of hybrid maize (*Zea mays* l.) in different levels and time of nitrogen application in Indo-Gangetic plains of eastern India. *Journal of Experimental Biology and Agricultural Sciences*, 6(6), 929–935. https://doi.org/10.18006/2018.6(6).929.935

Begizew, G., & Desalegn, C. (2019). Response of maize phenology and grain yield to various nitrogen rates and plant spacing at Bako, West Ethiopia. *Open Journal of Plant Science*, 4(1), 009–014. https://doi.org/10.17352/ojps.000016

Bk, A., Shrestha, J., & Subedi, R. (2018). Grain yield and yield attributing traits of maize genotypes under different planting dates. *Malaysian Journal of Sustainable Agriculture*, 2(2), 06–08. https://doi.org/10.26480/mjsa.02.2018.06.08

Chen, S., Liu, W., Morel, J., Parsons, D., & Du, T. (2023). Improving yield, quality, and environmental co-benefits through optimized irrigation and nitrogen management of hybrid maize in Northwest China. *Agricultural Water Management*, 290, 108577. https://doi.org/10.1016/j.agwat.2023.108577

Deng, H., Pan, X., Zhang, H., Xiao, Z., Xiao, R., Zhao, Z., & Chen, T. (2023). Comprehensive Regulation of Water–Nitrogen Coupling in Hybrid Seed Maize in the Hexi Oasis Irrigation Area Based on the Synergy of Multiple Indicators. *Water*, 15(22), 3927. https://doi.org/10.3390/w15223927

Dhakal, S., Sah, S. K., Amgain, L. P., & Dhakal, K. H. (2022). Maize cultivation: Present status, major constraints and farmer's perception at Madichaur, Rolpa. *Journal of Agriculture and Forestry University*, 5(1), 125–131. https://doi.org/10.3126/jafu.v5i1.48454

Dhital, G., Marahatta, S., Karki, T. B., & Basnet, K. B. (2022). Response of Different Levels of Nitrogen and Plant Population to Grain Yield of Winter Hybrid Maize in Chitwan Valley. *Agronomy Journal of Nepal*, 6(1), 59–68. https://doi.org/10.3126/ajn.v6i1.47938

Durbar, S. (2016). Statistical Information on Neplalese Agriculture Government of Nepal Ministry of Agricultural Development Monitoring, Evaluation and Statistics Division Agri Statistics Section. pp. 1–219.

Hammad, H. M., Abbas, F., Ahmad, A., Farhad, W., Wilkerson, C. J., & Hoogenboom, G. (2018). Evaluation of Timing and Rates for Nitrogen Application for Optimizing Maize Growth and Development and Maximizing Yield. *Agronomy Journal*, 110(2), 565–571. https://doi.org/10.2134/agronj2017.08.0466

Hammad, H. M., Chawla, M. S., Jawad, R., Alhuqail, A., Bakhat, H. F., Farhad, W., Khan, F., Mubeen, M., Shah, A. N., Liu, K., Harrison, M. T., Saud, S., & Fahad, S. (2022). Evaluating the Impact of Nitrogen Application on Growth and Productivity of Maize Under Control Conditions. *Frontiers in Plant Science*, 13, 885479. https://doi.org/10.3389/fpls.2022.885479

Haraga, L.-C., & Ion, V. (2023). The Effects of Side-Dressing Different Rates and Release Types of Nitrogen Fertilizer on Hybrid Seed Maize Production. *Romanian Agricultural Research*, 40, 429–438. https://doi.org/10.59665/rar4040

Jyosthna, N., Manjulatha, G., Mahesh, N., & Shakher, K. C. (2023). Impact of Tillage and Nitrogen Management Practices on Growth and Yield of Rabi Maize (*Zea mays* L.). *International Journal of Environment and Climate Change*, 13(10), 4194–4201. https://doi.org/10.9734/ijecc/2023/v13i103096

K.C, R., Bhatta, D., Lamsal, A., & Koirala, S. (2021). Effect of different doses of nitrogen on growth, yield and yield attributes of spring maize in Madichaur, Rolpa, Nepal. *International Journal of Agricultural and Applied Sciences*, 2(2), 120–125. https://doi.org/10.52804/ijaas2021.2218

Kapela, K., Sikorska, A., Niewęgłowski, M., Krasnodębska, E., Zarzecka, K., & Gugała, M. (2020). The Impact of Nitrogen Fertilization and the Use of Biostimulants on the Yield of Two Maize Varieties (*Zea mays* L.) Cultivated for Grain. *Agronomy*, 10(9), 1408. https://doi.org/10.3390/agronomy10091408

Karki, M., Panth, B. P., Subedi, P., GC, A., & Regmi, R. (2020). Effect of Different Doses of Nitrogen on Production of Spring Maize (Zea Mays) in Gulmi, Nepal. *Sustainability in Food and Agriculture*, 1(1), 01–05. https://doi.org/10.26480/sfna.01.2020.01.05

KC, G., Karki, T. B., Shrestha, J., & Achhami, B. B. (2015). Status and prospects of maize research in Nepal. *Journal of Maize Research and Development*, 1(1), 1–9. https://doi.org/10.3126/jmrd.v1i1.14239

Khaliq, T., Ahmad, A., Hussain, A., Ranjha, A. M., & Ali, M. A. (2008). Impact of Nitrogen Rates on Growth, Yield, and Radiation Use Efficiency of Maize Under Varying Environments. *Pakistan Journal of Agricultural Science*, 45(3), 1–7.

Kumar, P., Scholar, M. S., Kumar, M., Kishor, K., & Kumar, R. (2018). Effect of nutrient management on yield and yield attributes of Maize (*Zea mays* L.) under different tillage practices. *Journal of Pharmacognosy and Phytochemistry*, 7(2), 807-810.

Lakshmi, Y. S., Sreelatha, D., & Pradeep, T. (2020). Performance Evaluation of Sweetcorn with Different Levels of Irrigation and Nitrogen through Drip during Post Monsoon Season at Rajendranagar, Hyderabad, India. *International Journal of Environment and Climate Change*, 362–372. https://doi.org/10.9734/ijecc/2020/v10i1230311

Li, G., Zhao, B., Dong, S., Zhang, J., Liu, P., & Lu, W. (2020). Controlled-release urea combining with optimal irrigation improved grain yield, nitrogen uptake, and growth of maize. *Agricultural Water Management*, 227, 105834. https://doi.org/10.1016/j.agwat.2019.105834

Li, Z., Wang, G. Y., Khan, K., Yang, L., Wang, Y., Chi, Y. X., & Zhou, X. (2023). Irrigation Combines with Nitrogen Application to Optimize Soil Carbon and Nitrogen, Increase Maize Yield, and Nitrogen Use Efficiency [Preprint]. https://doi.org/10.21203/rs.3.rs-3343343/v1

Mahmood, M., Maaz Maqsood, M., Hussain Awan, T., Tahir Mahmood, M., Maqsood, M., & Sarwar, R. (2001). Effect of different levels of nitrogen and intra-row plant spacing on yield and yield components of maize. *African Journal of Agricultural Research*, 38(2), 1-2.

Marahatta, S. (2020). Nitrogen levels influence barrenness and sterility of maize varieties under different establishment methods during hot spring in western Terai of Nepal. *Journal of Agriculture and Forestry University*, 117–127. https://doi.org/10.3126/jafu.v4i1.47056

Modolo, L. V., da-Silva, C. J., Brandão, D. S., & Chaves, I. S. (2018). A minireview on what we have learned about urease inhibitors of agricultural interest since mid-2000s. *Journal of Advanced Research*, 13, 29–37. https://doi.org/10.1016/j.jare.2018.04.001

Nasar, J., Zhao, C. J., Khan, R., Gul, H., Gitari, H., Shao, Z., Abbas, G., Haider, I., Iqbal, Z., Ahmed, W., Rehman, R., Liang, Q. P., Zhou, X. B., & Yang, J. (2023). Maize-soybean intercropping at optimal N fertilization increases the N uptake, N yield and N use efficiency of maize crop by regulating the N assimilatory enzymes. *Frontiers in Plant Science*, 13, 1077948. https://doi.org/10.3389/fpls.2022.1077948

Nduwimana, D. (2020). Optimizing Nitrogen Use Efficiency and Maize Yield under Varying Fertilizer Rates in Kenya. *International Journal of Bioresource Science*, 7(2), 63-73. https://doi.org/10.30954/2347-9655.02.2020.4

Okab, S. I., & Abed, Z. A. (2022). Effect of Nitrogen Fertilizers on Growth and Yield Traits of Maize. *Iraq Journal of Market Research and Consumer Protection*, *14*(2), 40–49. https://doi.org/10.28936/jmracpc14.2.2022.(6)

Onasanya, R. O., Aiyelari, O. P., Onasanya, A., Oikeh, S., Nwilene, F. E., & Oyelakin, O. O. (2009). Growth and Yield Response of Maize (*Zea mays* L.) to Different Rates of Nitrogen and Phosphorus Fertilizers in Southern Nigeria. *World Journal of Agricultural Sciences*, 5(4), 400-407.

Owais, M., Afridi, M. Z., Iqbal, W., Saleem, M. A., Noor, E., Salman, M., Khan, S. J., & Kalim, M. (2023). Vigor and viability of maize seeds as affected by nitrogen and potassium levels. *Journal of Xi'an Shiyou University, Natural Science Edition*, 19(05), 524-529.

Raniro, H. R., Oliveira, F., Araujo, J. O., & Christoffoleti, P. J. (2023). Broadcast nitrogen application can negatively affect maize leaf area index and grain yield components under weed competition. *Farming System*, 1(3), 100047. https://doi.org/10.1016/j.farsys.2023.100047

Sabagh, A. EL, Majid, M. A., Islam, M. S., Hasan, M. K., Saddam, M. O., Barutcular, C., Ratnasekera, D., Abdelaal, Kh. A. A., & Islam, M. S. (2017). Influence of varying nitrogen levels on growth, yield and nitrogen use efficiency of hybrid maize (*Zea mays*). *Journal of Experimental Biology and Agricultural Sciences*, 5(2), 134–142. https://doi.org/10.18006/2017.5(2).134.142

Sandhu, N., Sethi, M., Kumar, A., Dang, D., Singh, J., & Chhuneja, P. (2021). Biochemical and Genetic Approaches Improving Nitrogen Use Efficiency in Cereal Crops: A Review. *Frontiers in Plant Science*, 12, 657629. https://doi.org/10.3389/fpls.2021.657629

Sharifi, R. S., & Namvar, A. (2016). Effects of time and rate of nitrogen application on phenology and some agronomical traits of maize (*Zea mays* L.). *Biologija*, 62(1), xx-xx. https://doi.org/10.6001/biologija.v62i1.3288

Sharma, L. K., Zaeen, A. A., Bali, S. K., & Dwyer, J. D. (2018). Improving Nitrogen and Phosphorus Efficiency for Optimal Plant Growth and Yield. In New Visions in Plant Science. InTech. https://doi.org/10.5772/intechopen.72214

Sharma, R., Adhikari, P., Shrestha, J., & Acharya, B. P. (2019). Response of maize (Zea mays L.) hybrids to different levels of nitrogen. *Archives of Agriculture and Environmental Science*, 4(3), 295–299. https://doi.org/10.26832/24566632.2019.040306

Shrestha, J. (2015, September 29). Growth and Productivity of Winter Maize (*Zea mays* L.) Under Different Levels of Nitrogen and Plant Population. Universal-Publishers.

Shrestha, J., Chaudhary, A., & Pokhrel, D. (2018). Application of nitrogen fertilizer in maize in Southern Asia: a review. *Peruvian Journal of Agronomy*, 2(2), 22. https://doi.org/10.21704/pja.v2i2.1201

Shrestha, J., Nath Yadav, D., Prasad Amgain, L., & Prasad Sharma, J. (2018). Effects of Nitrogen and Plant Density on Maize (*Zea mays* L.) Phenology and Grain Yield. *Current Agriculture Research Journal*, 6(2), 175–182. https://doi.org/10.12944/carj.6.2.06

Singh, J., Partap, R., Singh, A., Kumar, N., & K. (2021). Effect of Nitrogen and Zinc on Growth and Yield of Maize (*Zea mays* L.). *International Journal of Bio-Resource and Stress Management*, 12(3), 179–185. https://doi.org/10.23910/1.2021.2212

Su, W., Ahmad, S., Ahmad, I., & Han, Q. (2020). Nitrogen fertilization affects maize grain yield through regulating nitrogen uptake, radiation and water use efficiency, photosynthesis and root distribution. *PeerJ*, 8, 10291. https://doi.org/10.7717/peerj.10291

Sution, Hatta, M., Arsjad, L. M. G., & Marssinai, R. (2021). The effect of nitrogen fertilizer on hybrid maize yields under the shade of coconut trees. *E3S Web of Conferences*, 306, 04011. https://doi.org/10.1051/e3sconf/202130604011

Szabó, A., Széles, A., Illés, Á., Bojtor, C., Mousavi, S. M. N., Radócz, L., & Nagy, J. (2022). Effect of Different Nitrogen Supply on Maize Emergence Dynamics, Evaluation of Yield Parameters of Different Hybrids in Long-Term Field Experiments. *Agronomy*, 12(2), 284. https://doi.org/10.3390/agronomy12020284

Tanko, M. U., & Momohjimoh, Y. (2022). Growth and yield performances of three maize cultivars (*Zea mays* L.) as influenced by time of N-fertilizer application. *Journal of Innovative Agriculture*, 9(2), 42–49. https://doi.org/10.37446/jinagri/rsa/9.2.2022.42-49

Timsina, K. P., Ghimire, Y. N., & Lamichhane, J. (2016). Maize production in mid hills of Nepal: from food to feed security. *Journal of Maize Research and Development*, 2(1), 20–29. https://doi.org/10.3126/jmrd.v2i1.16212

Tirfi, A. G. (2023). Effect of different nitrogen dose on growth and yield characteristics of hybrid maize (*Zea mays* L.) Varieties at Sundar bazar, Lamjung. *Malaysian Journal of Sustainable Agriculture*, 7(2), 65-71.

Ullah, H., Tariq, M., Khan, M. O., Shah, T., Khan, N. A., Hussain, A., Bahadar, G., Ikramullah, M., & Muhammad, S. (2023). Influence of Nitrogen and Phosphorus on Yield of Maize. *International Journal of Agricultural and Statistical Sciences*, 19(1), 381. https://doi.org/10.59467/ijass.2023.19.381

Uzun, S., Özaktan, H., & Uzun, O. (2020). Effects of Different Nitrogen Dose and Sources as Top-Dressing on Yield and Silage Quality Attributes of Silage Maize. *Anais Da Academia Brasileira de Ciências*, 92(1), e20190030. https://doi.org/10.1590/0001-3765202020190030

Wang, L., Leghari, S. J., Wu, J., Wang, N., Pang, M., & Jin, L. (2023a). Interactive effects of biochar and chemical fertilizer on water and nitrogen dynamics, soil properties and maize yield under different irrigation methods. *Frontiers in Plant Science*, 14, 1230023. https://doi.org/10.3389/fpls.2023.1230023

Wang, L., Yu, B., Ji, J., Khan, I., Li, G., Rehman, A., Liu, D., & Li, S. (2023b). Assessing the impact of biochar and nitrogen application on yield, water-nitrogen use efficiency and quality of intercropped maize and soybean. *Frontiers in Plant Science*, 14, 1171547. https://doi.org/10.3389/fpls.2023.1171547

Wu, X., Cai, X., Li, Q., Ren, B., Bi, Y., Zhang, J., & Wang, D. (2022). Effects of nitrogen application rate on summer maize (*Zea mays* L.) yield and water–nitrogen use efficiency under micro–sprinkling irrigation in the Huang–Huai–Hai Plain of China. *Archives of Agronomy and Soil Science*, 68(14), 1915–1929. https://doi.org/10.1080/03650340.2021.1939867

Yadav, G., Rai, S., Adhikari, N., Yadav, S. P. S., & Bhattarai, S. (2022). Efficacy of different doses of NPK on growth and yield of rice bean (*Vigna umbellata*) in Khadbari, Sankhuwasabha, Nepal. *Archives of Agriculture and Environmental Science*, 7(4), 488–494. https://doi.org/10.26832/24566632.2022.070401

Yang, M., Ma, S., Mei, F., Wei, L., Wang, T., & Guan, X. (2021). Adjusting nitrogen application in accordance with soil water availability enhances yield and water use by regulating physiological traits of maize under drip fertigation. *Phyton*, 90(2), 417–435. https://doi.org/10.32604/phyton.2021.013175

Żarski, J., & Kuśmierek-Tomaszewska, R. (2023). Effects of Drip Irrigation and Top Dressing Nitrogen Fertigation on Maize Grain Yield in Central Poland. *Agronomy*, 13(2), 360. https://doi.org/10.3390/agronomy13020360

Zhao, J., Qi, Y., Yin, C., & Liu, X. (2023). Effects of Nitrogen Reduction at Different Growth Stages on Maize Water and Nitrogen Utilization under Shallow Buried Drip Fertigated Irrigation. *Agronomy*, 14(1), 63. https://doi.org/10.3390/agronomy14010063

Zhao, X., Wang, S., Wen, T., Xu, J., Huang, B., Yan, S., Gao, G., Zhao, Y., Li, H., Qiao, J., Yang, J., Wu, L., Wang, H., Liu, T., & Mu, X. (2023). On correlation between canopy vegetation and growth indexes of maize varieties with different nitrogen efficiencies. *Open Life Sciences*, 18(1), 20220566. https://doi.org/10.1515/biol-2022-0566

Zhou, H., Wang, Y., Wang, J., Liu, H., Li, H., & Guo, J. (2023). Effects of Long-Term Organic–Inorganic Nitrogen Application on Maize Yield and Nitrogen-Containing Gas Emission. *Agronomy*, 13(3), 848. https://doi.org/10.3390/agronomy13030848