INSIGHTS-JOURNAL OF LIFE AND SOCIAL SCIENCES

INSIGHTS-JLSS
Insights-Journal of Life and Social Sciences

COMPARATIVE PERFORMANCE OF MAIZE (ZEA MAYS L.) VARIETIES UNDER NITROGEN LEVELS TACTICS FOR IMPROVED CROP YIELD AND QUALITY IN CHHAMOGARH VALLEY DISTRICT GILGIT, PAKISTAN

Original Article

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Conflict of Interest: None

Grant Support & Financial Support: None

Acknowledgment: The author gratefully acknowledges local farmers for their support and field access.

ABSTRACT

Background: Nitrogen is a fundamental macronutrient essential for chlorophyll production, protein synthesis, enzymatic activity, and cellular development in maize (*Zea mays* L.). It constitutes approximately 1% to 4% of the plant's dry matter and directly influences photosynthetic efficiency, vegetative growth, and reproductive success. In nitrogen-deficient soils, maize performance deteriorates significantly, resulting in stunted growth and reduced yields. Effective nitrogen management is therefore critical for maximizing maize productivity, especially in nutrient-sensitive regions like Gilgit-Baltistan.

Objective: This study aimed to evaluate the effects of varying nitrogen levels on the growth and yield performance of different maize varieties under the agroecological conditions of Chhamogarh, Gilgit, Pakistan.

Methods: A field experiment was conducted in kharif 2024 using a randomized complete block design (RCBD) with three replications. Four maize varieties—Azam, Pahari, Jalal, and Islamabad Gold—were tested under four nitrogen treatments: T1 = 0 kg ha^{-1} (control), T2 = 108 kg ha^{-1}, T3 = 120 kg ha^{-1}, and T4 = 132 kg ha^{-1}. Parameters recorded included seedling emergence, plant height, stem girth, number of internodes per plant, days to tasseling, biological yield, and grain yield. Data were analyzed using ANOVA in Statistix 8.1 software.

Results: Significant differences ($P < 0.05$) were observed across all variables. T4 (132 kg ha^{-1}) produced the highest plant height (182.4 cm), stem girth (13.1 cm), internodes (14.1), biological yield (14,567.7 kg ha^{-1}), and grain yield (4,198.4 kg ha^{-1}) in variety Pahari. Conversely, T1 (control) recorded the lowest values in all parameters.

Conclusion: The findings highlight that nitrogen application at 132 kg ha^{-1} substantially improves maize growth and yield, with Pahari emerging as the most responsive and high-performing variety under local conditions.

Keywords: Agronomic traits, Biological yield, Fertilization, Grain yield, Maize, Nitrogen, Zea mays.

INTRODUCTION

Maize (*Zea mays* L.) stands as the third most vital cereal crop globally, following rice and wheat, due to its multifaceted uses and adaptability across diverse agro-ecological zones. In Pakistan, it occupies an estimated 10.85 million hectares and thrives in temperate, subtropical, and tropical regions, underscoring its broad environmental compatibility. While globally celebrated for its role in food systems, in Pakistan, maize is primarily cultivated to meet the growing demand for animal feed and fodder. Its ability to be consumed in various forms—such as popped grains, green or cooked cobs—further enhances its versatility in both human and animal diets (1). With a rapid growth cycle, high yield potential, and capacity for year-round cultivation, maize has rightly earned the title "queen of cereals" (2). The crop contributes significantly to global grain output, accounting for more than 40% of total grain production annually, with Pakistan alone producing 46.31 million tons (3).

This exceptional performance is attributed in part to its inherent agronomic characteristics, including a short maturation period and high responsiveness to improved cultivation techniques. However, such productivity is heavily reliant on the availability and management of essential nutrients—particularly nitrogen (4). Maize is recognized as a nutrient-exhaustive crop, with nitrogen being the most critical element required throughout its growth cycle. The role of nitrogen is central in physiological and biochemical processes such as cell division, protein synthesis, and chlorophyll production, all of which are vital for photosynthesis and reproductive development (5). Studies have indicated that nitrogen contributes 1% to 4% of the plant's dry matter, and its deficiency, especially during the tasseling and silking stages, can lead to substantial yield reductions (6). Moreover, nitrogen facilitates the uptake and translocation of other vital nutrients, making it a cornerstone of balanced crop nutrition (7).

Despite its importance, determining the optimal nitrogen requirement for maize remains a complex challenge. Several interrelated factors—soil composition, regional climate conditions, cropping history, maize genotype, and existing nutrient levels—influence how effectively maize utilizes applied nitrogen (8). Consequently, a universal recommendation for nitrogen application is impractical. Instead, site-specific nutrient management practices must be adopted to ensure efficient use, minimize environmental losses, and enhance crop performance (9). The dynamic interaction between nitrogen availability and maize development highlights a critical knowledge gap: the absence of regionally tailored nitrogen management strategies that consider both agronomic and environmental variables (10). Addressing this gap is crucial for advancing sustainable maize production systems and ensuring food and feed security amid changing climatic and agricultural landscapes. The present study is, therefore, designed to evaluate the impact of different nitrogen levels on maize growth and productivity under local conditions. By investigating how nitrogen influences key physiological and agronomic parameters, this research aims to identify optimal fertilization strategies that maximize yield while promoting nutrient use efficiency.

METHODS

The study was conducted during the kharif season of 2024 in Chhamogarh Village, District Gilgit, Gilgit-Baltistan, Pakistan, to assess the c*omparative performance of maize (Zea mays L.) varieties under different nitrogen application strategies aimed at improving crop yield and quality.* The research site, located approximately 30.1 kilometers from Gilgit city, was selected based on its agricultural prominence, accessibility, proximity to the researcher's hometown, and the dominance of maize-based farming systems. The population in this area is primarily engaged in farming, relying entirely on irrigated agriculture, with wheat, maize, and lucerne (*Medicago sativa*) being the dominant crops. Maize is widely grown for both grain consumption and fodder, forming a significant part of the local dietary and livestock systems. A randomized complete block design (RCBD) was employed with three replications to ensure reliable statistical comparison. Each net plot measured 4 meters by 3 meters (12 m^2), and four maize varieties—Azam, Pahari, Jalal, and Islamabad Gold—were evaluated. The experiment involved four nitrogen levels as treatments, which were correctly labeled and consistently applied as follows: T1 = 0 kg ha^{-1} (Control), T2 = 108 kg ha^{-1} (10% below the recommended dose), T3 = 120 kg ha^{-1} (Recommended dose), and T4 = 132 kg ha^{-1} (10% above the recommended dose). These nitrogen levels were selected to capture the crop's response to a gradient of nutrient availability, and to identify the most efficient dose for optimal growth and yield performance under local conditions.

Land preparation was carried out mechanically to ensure uniform seedbeds across all plots. Maize seeds were sown according to varietal spacing recommendations. Nitrogen fertilizer was applied using a split-application method: 50% of the assigned nitrogen dose was applied as a basal treatment at sowing, while the remaining 50% was top-dressed during the tasseling stage. This approach aligns with agronomic best practices to enhance nitrogen use efficiency and minimize nutrient losses. All other cultivation practices, such as irrigation, weeding, and pest management, were maintained uniformly across plots. At crop maturity, data were collected for key agronomic and phenological traits, including seedling emergence, plant height (cm), stem girth (cm), number of internodes per plant, days to tasseling, biological yield (kg ha^{-1}), and grain yield (kg ha^{-1}). The parameter "days to tasseling" was specifically analyzed across all treatment and variety combinations, as presented in the results, revealing a decreasing trend in tasseling duration with increasing nitrogen application.

Statistical analysis of the recorded data was conducted using Statistix 8.1 software (Statistix, 2006). Analysis of variance (ANOVA) was used to determine significant differences among treatments and varieties. Where appropriate, treatment means were compared using post-hoc tests to identify statistically meaningful differences.

No human or animal subjects were involved in the study; therefore, formal Institutional Review Board (IRB) or ethical committee approval was not applicable. Nonetheless, ethical standards for field-based agronomic research were fully observed. Local farmers were informed of the research activities, and consent for land use and observational access was obtained in accordance with local norms and community expectations.

RESULTS

Maize varieties responded significantly ($P<0.05$) to varying nitrogen levels across all measured parameters. Days to seedling emergence decreased with increasing nitrogen application. At 132 kg ha^{-1}, the shortest emergence times were observed in Islamabad Gold (6.8 days), Jalal (6.9 days), Pahari (7.8 days), and Azam (7.6 days). Conversely, in the absence of nitrogen (0 kg ha^{-1}), the longest emergence durations were recorded, ranging from 9.7 days in Jalal to 10.2 days in Pahari. Plant height increased consistently with higher nitrogen rates. The maximum height was observed under 132 kg ha^{-1}, with Pahari reaching 182.4 cm, followed by Azam (178.9 cm), Islamabad Gold (179.1 cm), and Jalal (174.8 cm). The lowest plant heights were noted in the control treatment, with Jalal at 145.1 cm and Azam at 149.8 cm. Stem girth followed a similar trend, showing a positive correlation with nitrogen levels. The highest girths were recorded at 132 kg ha^{-1} in Pahari (13.1 cm), Azam (12.5 cm), Islamabad Gold (12.3 cm), and Jalal (11.5 cm). The smallest stem girths were observed without nitrogen, ranging between 8.5 cm and 10.1 cm across all varieties.

The number of internodes per plant also increased with nitrogen availability. At 132 kg ha^{-1}, Pahari produced the most internodes (14.1), followed by Azam (13.5), Islamabad Gold (13.2), and Jalal (12.4). The lowest internode counts were seen in the control, ranging from 9.8 to 11.3. Days taken to tasseling decreased with increasing nitrogen application. The shortest durations were recorded under 132 kg ha^{-1}, with Pahari tasseling in 64.8 days, followed by Azam (66.6 days), Islamabad Gold (66.5 days), and Jalal (67.2 days). In contrast, without nitrogen, tasseling was delayed, extending to 69.9 days in Jalal and 69.4 days in Azam. Biological yield significantly improved with nitrogen application. The highest biological yields were obtained at 132 kg ha^{-1}, with Pahari achieving 14,567.7 kg ha^{-1}, followed by Azam (13,749.7 kg ha^{-1}), Islamabad Gold (12,672.8 kg ha^{-1}), and Jalal (11,325.2 kg ha^{-1}). The lowest yields were observed in the control plots, ranging from 6,135.4 kg ha^{-1} in Jalal to 7,038.1 kg ha^{-1} in Pahari.

Grain yield also increased substantially with nitrogen application. The maximum grain yield was recorded at 132 kg ha^{-1} in Pahari (4,198.4 kg ha^{-1}), Islamabad Gold (4,022.5 kg ha^{-1}), Azam (3,925.0 kg ha^{-1}), and Jalal (3,867.1 kg ha^{-1}). The lowest grain yields were seen in the control plots, ranging from 1,876.3 kg ha^{-1} to 2,031.6 kg ha^{-1} across all varieties. Analysis of the collected data revealed that increasing nitrogen application positively influenced all observed growth and yield parameters across the four maize varieties. A consistent pattern was noted where the highest nitrogen level (132 kg ha^{-1}) resulted in the most favorable outcomes. Seedling emergence occurred earliest under this treatment, with Islamabad Gold showing the quickest emergence (6.8 days), compared to delayed emergence under no nitrogen (up to 10.2 days in Pahari). Plant height followed a similar trend, with Pahari reaching the maximum height of 182.4 cm at 132 kg ha^{-1} and Jalal exhibiting the lowest height of 145.1 cm under the control. Stem girth was also significantly improved, with Pahari (13.1 cm) and Azam (12.5 cm) recording the greatest thickness under the highest nitrogen treatment. Nitrogen application enhanced the number of internodes per plant, with Pahari again leading at 14.1 internodes under 132 kg ha^{-1}, while control plots exhibited the fewest. Days to tasseling decreased as nitrogen levels increased, suggesting earlier reproductive development, with Islamabad Gold tasseling in 66.5 days at the highest nitrogen rate compared to 69.1 days without nitrogen. Biological yield showed a substantial increase, with Pahari achieving 14,567.7 kg ha^{-1} under 132 kg ha^{-1} nitrogen, while the control treatment yielded nearly half that amount. Similarly, grain yield was maximized in the same treatment, peaking at 4,198.4 kg ha^{-1} in Pahari, followed by Azam, Jalal, and Islamabad Gold. Notably, all varieties performed progressively better as nitrogen levels increased, highlighting a direct, positive relationship between nitrogen input and maize productivity.

Table 1: Comparative Performance of Maize (*Zea mays* L.) Varieties Under Varying Nitrogen Levels for Seedling Emergence, Plant Height, Stem Girth, and Internode Number

Treatment	Trait	Azam	Pahari	Jalal	Islamabad Gold
T1 = 0 kg/ha	Seedling Emergence (days)	10.1	10.2	9.7	9.9
T2 = 108 kg/ha		9.4	9.8	8.2	8.6
T3 = 120 kg/ha		8.5	8.7	7.5	7.1
T4 = 132 kg/ha		7.6	7.8	6.9	6.8
T1 = 0 kg/ha	Plant Height (cm)	149.8	155.3	145.1	150.2
T2 = 108 kg/ha		164.4	168.1	155.4	161.5
T3 = 120 kg/ha		169.2	171.2	163.7	170.3
T4 = 132 kg/ha		178.9	182.4	174.8	179.1
T1 = 0 kg/ha	Stem Girth (cm)	9.7	10.1	8.5	9.8
T2 = 108 kg/ha		10.6	11.3	9.7	10.5
T3 = 120 kg/ha		11.7	12.2	10.4	11.6
T4 = 132 kg/ha		12.5	13.1	11.5	12.3
T1 = 0 kg/ha	Number of Internodes	10.8	11.3	9.8	10.6
T2 = 108 kg/ha		11.8	12.5	10.4	11.5
T3 = 120 kg/ha		12.8	13.4	11.2	12.7
T4 = 132 kg/ha		13.5	14.1	12.4	13.2

Table 2: Comparative performance of maize (Zea mays L.) days taken to tasseling

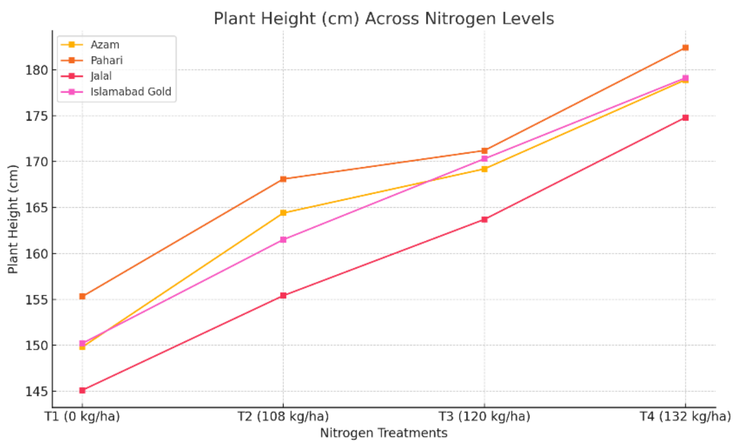
Treatments	Varieties			
	Azam	Pahari	Jalal	Islamabad gold
T1=No N=00 kg ha^{-1}	69.4 d	68.2 d	69.9 d	69.1 d
T2=N= 108 kg ha^{-1}	68.3 c	66.5 c	69.1 c	68.4 c
T3=N= 120 kg ha^{-1}	67.5 b	65.1 b	68.5 b	67.3 b
T4=N= 132 kg ha^{-1}	66.6 a	64.8 a	67.2 a	66.5 a

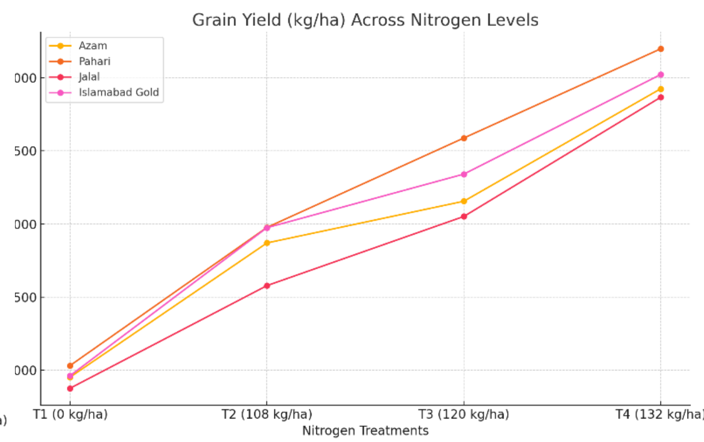
Table 3: Comparative performance of maize (Zea mays L) Biological yield kg ha^{-1}

Treatments	Varieties			
	Azam	Pahari	Jalal	Islamabad gold
T1=No N=00 kg ha^{-1}	6249.7 d	7038.1 d	6135.4 d	6359.7 d
T2=N=108 kg ha^{-1}	9149.7 c	1052.5 c	9014.7 c	9256.4 c
T3=N=120 kg ha^{-1}	10416.3 b	13623.6 b	10024.5 b	11376.2 b
T4=N= 132 kg ha^{-1}	13749.7 a	14567.7 a	11325.2 a	12672.8 a

Table 4: Comparative performance of maize (Zea mays L.) Varieties under nitrogen levels tactics for improved crop yield and quality (Grain yield kg ha^{-1})

Treatments	Varieties			
	Azam	Pahari	Jalal	Islamabad gold
T1=No Nitrogen00 kg ha^{-1}	1952.3 d	2031.6 d	1876.3 d	1962.3 d
T2=Nitrogen 108 kg ha^{-1}	2870.3 c	2976.5 c	2578.4 c	2974.7 c
T3=Nitrogen 120 kg ha^{-1}	3155.7 b	3588.2 b	3051.5 b	3341.3 b
T4=Nitrogen 132 kg ha^{-1}	3925.0 a	4198.4 a	3867.1 a	4022.5 a





DISCUSSION

The findings of this study confirm the critical role of nitrogen in enhancing the vegetative growth, phenological development, and yield performance of maize. As a fundamental macronutrient, nitrogen serves as a core component of amino acids, nucleic acids, and chlorophyll, directly influencing plant metabolism, growth rate, and biomass accumulation (11). The progressive improvement in plant traits across increasing nitrogen levels aligns with earlier reports emphasizing nitrogen's necessity for vigorous growth and high productivity in maize crops (12). When applied at 132 kg ha^{-1}, nitrogen significantly improved seedling emergence, plant height, stem girth, number of internodes, and days to tasseling, which collectively contributed to enhanced biological and grain yields. These results corroborate earlier findings that maize responds favorably to sufficient nitrogen during critical growth phases, particularly the vegetative and early reproductive stages (13). Despite the well-established benefits of nitrogen, the relationship between its availability and maize growth is not linear. While higher nitrogen rates generally promoted better growth and yield, excessive nitrogen can sometimes induce excessive vegetative growth at the cost of reproductive efficiency (14). Over-fertilization may delay tasseling and silking, hinder kernel development, and ultimately reduce yield due to imbalanced source-sink relationships (15). However, within the range used in this study, no adverse effects were observed, suggesting that the maximum tested dose (132 kg ha^{-1}) remained within agronomically optimal limits under the given environmental and soil conditions (16). A clear gradient in response was noted across all varieties, with Pahari consistently showing superior performance, indicating varietal differences in nitrogen use efficiency and adaptability to local growing conditions (17).

The results also highlight the importance of integrating appropriate agronomic practices with nutrient management (18). Poor planting methods such as flat sowing, still common in various parts of Pakistan, limit crop potential despite favorable environmental conditions. Ridge planting has been recognized for improving soil aeration, water retention, and root proliferation, ultimately enhancing nitrogen uptake and crop performance (19). Yet, such techniques were not a variable in the present study and remain a missed opportunity for further improving maize productivity under similar nitrogen treatments. A strength of the current research lies in its robust experimental design and the use of four different maize varieties, providing comparative insights across genotypes. The consistent trends across varieties support the validity of the findings and reinforce the conclusion that nitrogen application is directly correlated with enhanced vegetative and reproductive development (20). However, the study has notable limitations. The investigation did not assess grain quality parameters such as protein content, starch composition, or nitrogen use efficiency (NUE), despite the study's stated aim to evaluate "quality." These omissions restrict the interpretability of findings in terms of nutritional value and post-harvest utility. Additionally, environmental parameters such as soil texture, organic matter content, and microclimatic variations were not extensively documented, though they significantly influence nutrient dynamics and crop performance.

Future studies should expand on these findings by incorporating biochemical quality indicators and evaluating NUE to determine the environmental sustainability of nitrogen use. Site-specific nutrient management strategies should also be explored, considering varying soil fertility statuses and maize genotypes. There is also a need for exploring the synergistic impact of nitrogen with other essential nutrients such as phosphorus and potassium, as nutrient interactions can modulate maize responses significantly. Inclusion of planting method comparisons, such as ridge versus flat sowing, under identical nitrogen treatments could provide actionable insights for smallholder farmers aiming to optimize both yield and resource efficiency. In summary, nitrogen application up to 132 kg ha^{-1} improved the morphological, phenological, and yield-related parameters of maize varieties, particularly in Pahari, under the conditions of Chhamogarh, Gilgit. While the results are promising, the lack of quality trait data and broader environmental profiling limits the study's application beyond its immediate context. Nonetheless, the study provides a foundational basis for improving nitrogen management practices and optimizing maize productivity in similar agroecological zones.

CONCLUSION

The findings of this study clearly demonstrate that nitrogen fertilization had a significant positive impact on the growth and yield of maize, with improvements observed consistently across all evaluated varieties. As nitrogen levels increased, so did key agronomic traits, supporting the critical role of this nutrient in enhancing plant vigor and productivity. Among the tested varieties, Pahari consistently outperformed others in terms of growth characteristics and yield potential, indicating its suitability for cultivation in the agro-climatic conditions of Chhamogarh, Gilgit. The study highlights the practical importance of optimizing nitrogen management for improved maize performance and suggests that adopting responsive varieties like Pahari, alongside proper nutrient application, can substantially contribute to sustainable crop production and food security in the region.

Author Contributions

Author	Contribution
Danish Manzoor*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Asif Ali Kaleri	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Urooj Rehmani	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Ghulam Hussain Wagan	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Zaheer Ahmed	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Abdul Qayoom Majeedano	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Talha Saeed	Contributed to study concept and Data collection Has given Final Approval of the version to be published
Asif Ali Jamali	Writing - Review & Editing, Assistance with Data Curation
Mughees Ul Hassan	Writing - Review & Editing, Assistance with Data Curation

Waheed Abbas	Writing - Review & Editing, Assistance with Data Curation

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