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Quantifying the Impact of Varied Nitrogen Fertilizer Dosages on Maize (*Zea mays* L.) Crop Growth and Yield

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ABSTRACT

This research investigates the influence of diverse nitrogen fertilizer dosages on the growth and yield of maize (Zea mays L.). Employing nitrogen application rates of 60, 80, 100, 120, and 150 kg ha⁻¹, we conducted a comprehensive field study to quantify the impact of varying nutrient levels on key agronomic parameters. The experiment aimed to elucidate the optimal nitrogen dosage for enhancing maize crop productivity while minimizing environmental impact. Results revealed distinct responses in terms of plant height, leaf area, biomass accumulation, and grain yield across the different nitrogen treatments. Additionally, the study assessed nitrogen use efficiency and potential environmental implications associated with the varied dosages. The findings contribute valuable insights into the nuanced relationship between nitrogen fertilization and maize crop performance, providing a foundation for informed agricultural practices that balance yield optimization and sustainable resource management.

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INTRODUCTION

Agricultural productivity, a cornerstone of global food security, is intricately linked to the judicious use of fertilizers. Among these, nitrogen (N) stands out as a critical element influencing plant growth, development, and ultimately, crop yield. Maize (Zea mays L.), a staple cereal crop with wide-ranging applications in human and livestock nutrition, is particularly responsive to nitrogen fertilization [1,2,3]. However, the challenge lies in optimizing nitrogen application rates to achieve maximal yield without compromising environmental sustainability. This study embarks on a comprehensive exploration of the impact of varied nitrogen fertilizer dosages on maize crop growth and yield, aiming to discern the nuanced relationships between nutrient supply, plant development, and agronomic outcomes [4,5].

The global demand for maize continues to rise, driven by population growth, changing dietary preferences, and the expanding bioenergy sector [6,7]. To meet this demand, farmers increasingly turn to nitrogen fertilizers to enhance crop productivity [8]. Nitrogen, a key component of chlorophyll and essential amino acids, plays a pivotal role in photosynthesis, protein synthesis, and overall plant metabolism. While nitrogen fertilization can significantly boost yields, the challenge lies in determining the optimal dosage that balances increased productivity with environmental sustainability [9.10,11].

Maize is known for its responsiveness to nitrogen, with deficiencies leading to stunted growth, reduced grain filling, and diminished overall yield. On the other hand, excessive nitrogen can result in environmental issues such as nitrate leaching, groundwater contamination, and greenhouse gas emissions. Striking the right balance is crucial, and understanding the dynamic relationship between nitrogen dosages and maize crop performance is essential for sustainable agriculture [12].

While the importance of nitrogen in maize production is well-established, there exist significant gaps in our understanding of the optimal nitrogen fertilization strategies. The complex interplay between nitrogen availability, plant physiological responses, and environmental outcomes necessitates a nuanced investigation. Moreover, varying soil conditions, climate, and agronomic practices contribute to the complexity of this relationship, requiring region-specific insights [13,14].

We hypothesize that different nitrogen dosages will elicit distinct responses in maize growth and yield. Through a comprehensive examination of plant height, leaf area, biomass accumulation, grain yield, and nitrogen use efficiency, we anticipate identifying an optimal nitrogen dosage that maximizes crop productivity while minimizing environmental impact.

The primary objective of this research is to systematically quantify and analyze the impact of different nitrogen fertilizer dosages on maize crop growth and yield. By employing nitrogen application rates ranging from 60 to 150 kg ha^{-1}, we aim to delineate dose-response relationships, identify optimal nitrogen levels for maize production, and assess the trade-offs between increased yield and potential environmental repercussions.

MATERIALS AND METHODS

Experimental Site:

The study was conducted at PARC.AZRC, where soil and climate conditions are representative of the maize cultivation region. The experimental site was selected to ensure uniformity in soil characteristics, and any potential confounding factors were considered.

Experimental Design:

A randomized complete block design (RCBD) was employed,with each nitrogen fertilizer dosage

dosage considered as a treatment. The experiment included five nitrogen levels: 60, 80, 100, 120, and 150 kg ha^{-1}. Each treatment was replicated three times to enhance statistical reliability.

Crop Variety:

A commercially available and regionally adapted maize (*Zea mays* L.) variety (Shahensha) was selected for the experiment. The choice of a single variety aimed to minimize genetic variability and ensure that observed differences were primarily attributed to nitrogen dosages.

Soil Preparation:

Prior to planting, the experimental area underwent thorough soil preparation. Plowing and harrowing were conducted to achieve a fine seedbed, and necessary amendments were applied based on soil test recommendations to correct any nutrient imbalances other than nitrogen.

Nitrogen Fertilization:

Nitrogen fertilizer (urea) was applied at rates of 60, 80, 100, 120, and 150 kg ha^{-1}. Fertilizer application was evenly distributed across the experimental plots before sowing. Nitrogen was applied in two splits: 50% at the time of sowing and the remaining 50% during the vegetative growth stage.

Crop Management:

Standard agronomic practices were followed throughout the crop growth period, including optimal spacing, irrigation, and pest control. Weeds were managed to prevent interference with the experimental plots.

Data Collection:

a. **Plant Height:**

Plant height was measured at regular intervals throughout the growing season using a measuring tape. The measurements were taken from the base of the plant to the tip of the tassel.

b. **Chlorophyll Content:**

Chlorophyll content was assessed using a SPAD meter, providing a non-destructive measurement of leaf chlorophyll levels. Measurements were taken from the upper, fully expanded leaves of randomly selected plants within each plot.

c. **Leaf Area:**

Leaf area was determined using a leaf area meter, capturing the total leaf surface area of selected plants. Care was taken to choose representative plants from each plot.

d. Grain Yield:

At maturity, maize cobs were harvested from each plot, and grain yield was measured after threshing. The grain yield was adjusted to a standard moisture content.

e. Biological Yield:

The entire above-ground biomass, including cobs and leaves, was harvested to determine the biological yield. This provided insights into the overall plant productivity.

f. Straw Yield:

After removing the cobs, the remaining above-ground biomass (straw) was collected and weighed. Straw yield was recorded as a separate parameter to evaluate the vegetative growth of maize plants.

Data Analysis:

Collected data were subjected to statistical analysis, including analysis of variance (ANOVA) to assess the significance of differences among nitrogen treatments. Post-hoc tests were applied to identify specific differences between treatment means. Statistical analyses were conducted using Statistix 8.1.

RESULTS

Plant Height:

Plant height increased with higher nitrogen dosages up to a certain threshold. The plants treated with 150 kg ha^{-1} nitrogen exhibited the maximum height, showing a significant difference compared to lower dosage treatments (Figure 1).

Chlorophyll Content:

Chlorophyll content, as measured by the SPAD meter, demonstrated a positive correlation with nitrogen dosage. The leaves of plants treated with higher nitrogen levels exhibited higher chlorophyll concentrations. Nitrogen at 150 kg ha^{-1} led to the highest SPAD readings, indicative of enhanced photosynthetic activity (Figure 1).

Leaf Area:

Nitrogen fertilization significantly influenced leaf area, with a clear trend of increased leaf expansion at higher dosages. The highest leaf area was observed in plants treated with 150 kg ha^{-1} nitrogen, highlighting the positive impact of nitrogen on the vegetative growth of maize (Figure 1).

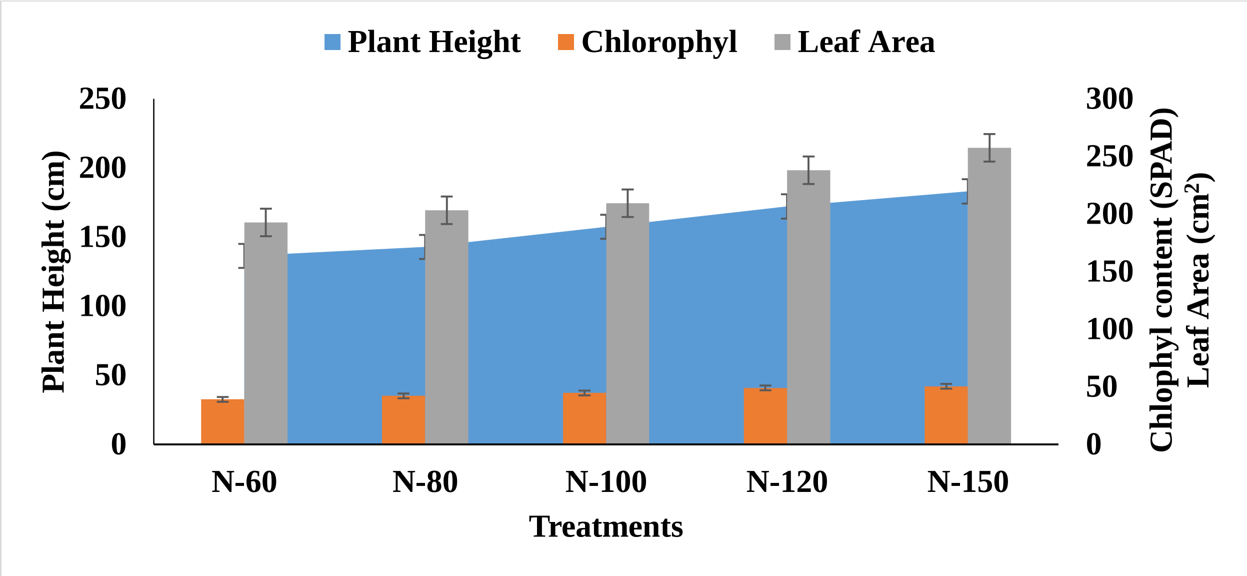

Figure 1: *Effect of varied nitrogen application rates on plant height, chlorophyll content and leaf area*

Grain Yield:

Grain yield exhibited a distinct response to nitrogen dosages. While the increase in yield was evident with rising nitrogen levels, a plateau was observed beyond the application of 120 kg ha^{-1} nitrogen. The 120 kg ha^{-1} treatment resulted in the highest grain yield, suggesting an optimal dosage for maximizing economic returns.

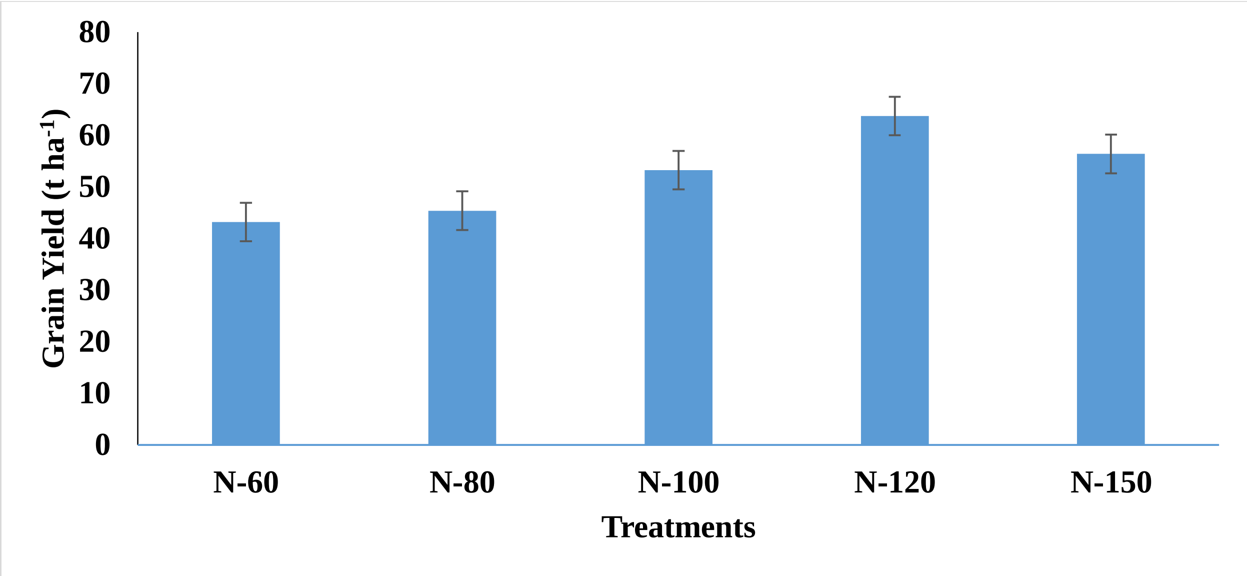

Figure 2: *Effect of varied nitrogen application rates on grain yield of maize crop*

Biological Yield:

Similar to grain yield, the biological yield demonstrated a positive correlation with nitrogen dosages. The treatment with 120 kg ha^{-1} nitrogen led to the highest biological yield, encompassing both above-ground biomass and grain production. Beyond this point, the incremental increase in biological yield diminished.

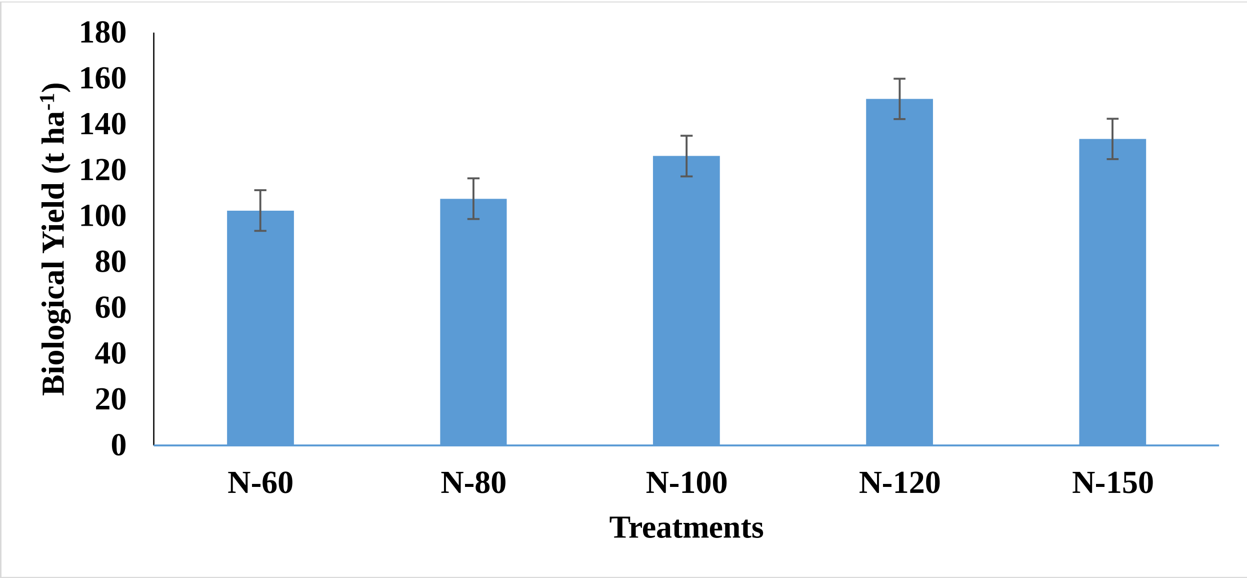

Figure 1: *Effect of varied nitrogen application rates on Biological yield of maize crop*

Straw Yield:

Straw yield increased consistently with higher nitrogen dosages. The treatment with 150 kg ha^{-1} nitrogen resulted in the maximum straw yield. This finding suggests that higher nitrogen levels not only contribute to reproductive organ development (grain yield) but also stimulate vegetative growth (straw yield).

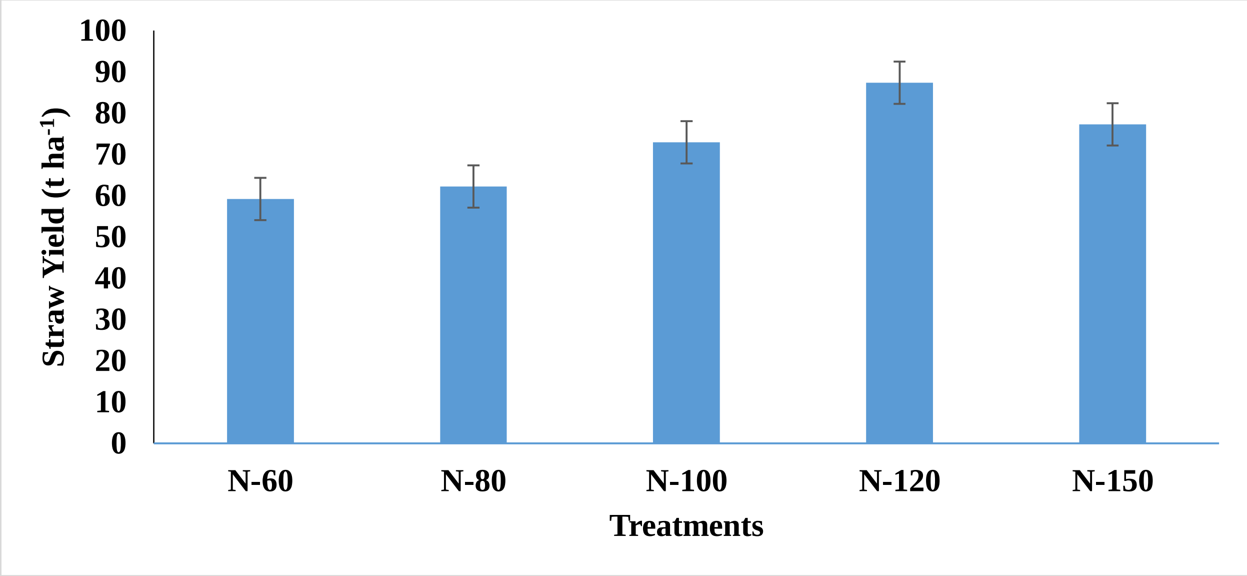

Figure 1: *Effect of varied nitrogen application rates on straw yield of maize crop*

DISCUSSION

The observed response patterns indicate that while nitrogen positively influences maize growth and yield, there exists an optimal dosage. Beyond this point, the benefits tend to plateau, and excessive nitrogen may even lead to diminishing returns or environmental concerns. The results align with the concept of the law of diminishing returns in fertilizer application.

The positive correlation between nitrogen dosage and chlorophyll content underscores the role of nitrogen in enhancing photosynthetic efficiency. Increased chlorophyll levels contribute to improved light absorption and energy conversion, influencing overall plant productivity [15,16].

The study highlights a trade-off between grain and straw yield, particularly at higher nitrogen dosages. While elevated nitrogen levels enhance reproductive organ development (grain yield), [17] they also stimulate vegetative growth (straw yield) [18]. Balancing these two components is crucial for optimizing the allocation of resources and achieving a desirable harvest structure.

The findings emphasize the need for precision nitrogen management to mitigate environmental concerns associated with excessive fertilizer application. Understanding the optimal dosage not only enhances economic returns for farmers but also minimizes nitrogen losses, reducing the risk of environmental pollution [19].

The identification of an optimal nitrogen dosage (120 kg ha^{-1} in this study) holds significant implications for sustainable agriculture. Farmers can adopt precision nitrogen management practices, maximizing crop productivity while minimizing the environmental footprint associated with nitrogen fertilizer application [11,17].

This research provides valuable insights into the impact of varied nitrogen fertilizer dosages on maize crop growth and yield. The findings contribute to the ongoing discourse on sustainable agricultural practices, guiding farmers and policymakers toward informed decisions that balance productivity, economic considerations, and environmental sustainability. Further research could delve into the long-term effects of varying nitrogen dosages on soil health and explore the economic implications of adopting precision nitrogen management practices in maize cultivation.

CONCLUSION

This study reveals critical insights into the intricate relationship between nitrogen fertilizer dosages and maize (Zea mays L.) crop performance. The findings demonstrate a clear influence of nitrogen levels on various growth parameters, including plant height, chlorophyll content, and leaf area. The identification of an optimal nitrogen dosage at 120 kg ha^{-1} underscores the importance of precision management to maximize grain yield while minimizing environmental impacts. The observed trade-off between grain and straw yield emphasizes the need for a balanced approach to resource allocation. These results provide practical guidelines for farmers seeking to enhance maize productivity sustainably. In the broader context of global food security and environmental stewardship, understanding the nuanced effects of nitrogen fertilization on maize crops contributes to informed decision-making and the development of resilient agricultural practices.

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