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Review Article

The Impact of Nitrogen Management on Wheat Production in Nepal

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A B S T R A C T

In Nepal, wheat is the third most cultivated crop, and nitrogen plays a pivotal role in crop growth and grain production. Effective nitrogen management is essential for enhancing productivity and ensuring optimal grain yield. This study investigates the influence of nitrogen rates on wheat grain yield, nitrogen content, uptake, and utilisation efficiency, aiming to establish guidelines for effective nitrogen application in wheat cultivation. A comprehensive review of existing literature was conducted to analyse the relationship between nitrogen application rates and various agronomic outcomes in wheat. The review focused on identifying the optimal nitrogen thresholds for maximising yield while minimising negative effects such as lodging. The findings indicate that while nitrogen is a vital nutrient that significantly affects grain yield and nitrogen utilisation efficiency, exceeding a certain nitrogen threshold does not confer additional benefits. Instead, excessive nitrogen application can lead to decreased yields due to lodging. Furthermore, the study highlights that tailored nitrogenous fertiliser applications based on soil requirements and wheat variety are crucial for optimising performance. Proper agronomic practices and timely nitrogen applications were identified as key factors in achieving higher yields. The review underscores the importance of balanced nitrogen management strategies in wheat production. By aligning nitrogen applications with soil needs and employing optimal agronomic practices, farmers can enhance yield potential and improve overall agricultural sustainability in Nepal.

Keywords: Nitrogen Management, Wheat Production, Grain Yield, Agronomic Practices

Introduction

Cereal production, predominantly centered on wheat, is on the rise globally, owing to its increasing demand. Wheat is the third most cultivated crop in Nepal.[1] Presently, wheat cultivation spans 716,000 hectares, yielding a total output of 2,145,000 metric tons, with a productivity rate of 2.33 tons per hectare.[2] This accounts for approximately 5.67% of the national agricultural gross domestic product.[3] The Terai region of Nepal accounts for 60% of wheat production, benefiting from its favourable climate and fertile soil conditions. Wheat is recognised as an excellent reservoir for

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proteins, fibres, vitamins, and minerals. It holds a significant place in diets and is consumed as a staple in diverse forms such as roti, bread, cakes, and pastries.

Nitrogen (N) plays an important role in plant physiological processes. Nitrogen influences plant growth and development, and the management of nutrients, especially nitrogen, and the adequate and timely application of nitrogen determine optimum crop production. More than the required nitrogen leads to losses in the form of nitrate leaching, greenhouse emissions, and soil acidification, which decreases crop production.[4] Residual nitrogen is lost through the environment by leaching, volatilisation, or indirectly by microorganisms.[5] Therefore, effective techniques are required for proper nitrogen uptake and efficient use in sustainable agricultural systems.[6]

This review provides insights into the ideal nitrogen dosage that is crucial for achieving maximum crop yield. It delves into how nitrogen application rates influence nitrogen uptake, content, and overall efficiency of the crop. The excessive use of fertilizers by farmers has contributed to a decline in soil fertility, subsequently diminishing the efficiency of nitrogen fertilization in plants. The emphasis should be on sustainable agricultural practices involving the provision of optimal nutrient levels to the plants.

Effect of nitrogen rate on grain yield

Nitrogen plays a significant role in crop growth and grain production. Proper management of nitrogen leads to higher productivity. A study on wheat[7] found that when different levels of nitrogen (60–120 kg N/ha) were supplied to wheat farms, 120 kg ha-1 resulted in the highest yield. Similarly, a study conducted on bread wheat[8] and southern Chile[9] reported that higher nitrogen application rates were associated with higher grain production. The application of nitrogen increases plant height, tiller, grain, and straw yield, which influences crop biological yield.[10]

A study on three varieties of bread wheat, Menze, Tse hay, and ET-13,[8] at nitrogen rates of 140, 240, and 360 kg ha-1, suggested that application rates beyond 240 kg ha-1 led to a reduction in grain production due to lodging. This result was similar to that of Guarda et al. (2004),[5] who suggested that the application of higher nitrogen leads to lodging and causes loss in crop yield. When the yield was compared between the local and improved varieties of bread wheat,[11] the yield was improved significantly by 31%. Similarly, Ercoli et al. (2008)[12] compared the yields of old and new varieties of wheat and discovered that the new varieties produced higher yields. This is because the new variety exploits the soil more effectively than the old variety.

Relation between plant height and yield

It has been shown to affect plant height.[13] Ali et al., 2000[14] conducted experiments with different nitrogen rates and found that the maximum plant height (98.33 cm) was found at a nitrogen rate of 125 kg ha-1, followed by 100 and 150 kg ha-1. These results are similar to those reported by Gwal et al. (1999)[15] and Jan et al. (2002),[16] who also reported that an increase in the nitrogen rate increased plant height. These results were similar to those reported by Sharma et al. (2005),[17] Amare et al. (2013),[18] and Muhammad et al. (2016),[19] who suggested that an increase in nitrogen rate increased wheat plant height.

Relation between number of tillers/plant and yield

Tillers and plants are important characteristics of crop production.[20,21] It has been observed that increasing the nitrogen application rate significantly increases the number of tillers per plant.[22] This observation was similar to that of Ali et al. (2011)[14], who observed that increasing nitrogen rates resulted in a maximum number of tillers m2 (373.8) at a nitrogen rate of 130 kg N ha-1. Ali et al. (2011)[14] observed that a nitrogen application rate of 180 kg ha-1 had a similar effect on tiller number. This is similar to the observations of Hameed et al. (2003)[23], who also stated that increasing nitrogen application increases the number of tillers. Similarly, Amare et al. (2013)[18] observed that nitrogen has a positive effect on crop nutrients, thereby increasing the number of tillers. Furthermore, Bundy and Andraski (2004)[24] observed that nitrogen has a strong effect on plant tillers.

Relation between number of grains/ear and yield

The wheat yield is directly related to the number of grains and ears (Savin and Slafer, 1991).[25] Pochaba and Wegrzyn (2001)[26] suggested that grains/ears, kernel weight, and plant height directly affect wheat yield. This result is similar to that reported by,[27] who found that the grain number was the most significant determinant of wheat yield. This is similar to the results of Iqbal et al. (2010),[28] who suggested that different nitrogen rates and crop varieties affect the number of grains per area. Several factors affect the number of grains, such as genotype, class of wheat, cultural practices, and climatic conditions of the field.

Relation between kernel/spike and yield

The number of kernels/spikes is a significant yield-contributing characteristic of crop yields. They also observed that the number of kernels per spike increased with increasing nitrogen rate. The highest number of kernels was found at the nitrogen application rate of 46 kg ha-1, followed by 30 kg ha-1.

Tabatabaii et al. (2011)[29] reported that the application of nitrogen increased grain/spike as material transition in the phloem increased cell division and growth. This observation was similar to that reported by Mirza et al. (2018),[30] who also reported that increasing the nitrogen rate significantly

affected the kernels per spike in wheat. Similarly, Omar et al. (2023)[31] reported that the number of grains per spike increases with increasing nitrogen levels. Several other authors have stated that an increase in N application rate does not necessarily result in a higher yield.[32] Even in areas with low nitrogen, such as Nepal, Rawal et al. (2022)[33] suggested that an increase in nitrogen rates has almost the same effect on crop yield.

This is because nitrogen requirements of wheat differ in different places and from year to year. Research performed at different sites[32] has concluded that the optimum nitrogen rate for crops differs from place to place and year to year. Raun et al. (2019)[34] showed that the environment can be unpredictable in determining the N uptake and grain yield. Instead, crop yield depends on the climate of the location and the agronomic practices performed by the farmer.

Effect of nitrogen rate on nitrogen content and uptake

The nitrogen content was significantly affected by the rate at which nitrogen was provided to the crop. The experiment was performed at different nitrogen rates ranging from 30 to 120 kg ha-1. The highest yield was observed at 120, and the lowest at 0 kg ha^{-1}. Similar results were obtained when the nitrogen application rate was increased from 0 to 120 kg ha-1 (Alemu et al., 2016).[35] When the experiment was performed on three different varieties of wheat with higher rates of nitrogen at 120, 240, and 360 kg ha-1 (Belete et al., 2018),[8] they also reported that the application of a nitrogen rate of 360 kg ha-1 resulted in an increase in the nitrogen content of grain by 2.7%.

This result was similar to that of Amsal and Tanner (2001),[36] who suggested that higher nitrogen uptake is required for high-yielding varieties at higher nitrogen rates. This was due to the significant differences in growth rather than in the total nitrogen percentage. Lopez-Bellido et al. (2004)[37] reported that differences in nitrogen uptake were due to better physiological traits in different crop varieties.

The total nitrogen uptake was highest at 120 kg ha^{-1} and lowest at 0 kg ha^{-1} .[7] Belete et al. (2018[8] reported that, when three varieties of bread wheat were treated with nitrogen rates of 360, 240, and 180 kg ha-1, the highest nitrogen uptake was observed at 360 kg ha-1, followed by 240 and 180 kg ha-1. The highest nitrogen uptake results from the highest nitrogen supply (Motzoetal,2004).[38] There was a direct relationship between nitrogen supply and nitrogen uptake by the crop. They also suggested a direct relationship between nitrogen uptake and grain yield.

The result from two years 2014 and 2015 showed that nitrogen content and uptake both increased nitrogen rate upto 90 kg N ha-1 whereas it was also found that nitrogen content and uptake had no significant at nitrogen rate 120 kg ha-1. Patel et al. (1996)[39] reported nitrogen content of wheat increased up nitrogen rate of 120 kg ha-1. This may be because of the greater absorption of nitrogen at a higher rate. Verma and Joshi (1998)[40] found a similar result: the higher the nitrogen rate, the higher the nitrogen content and uptake.

Walsh et al. (2022)[41] reported that the experiment was performed in different locations at the highest nitrogen rate of 336 kg ha-1 and 252 and 168 kg ha-1. The highest nitrogen uptake was 168 kg ha-1 at a few locations, and the highest nitrogen uptake was 252 kg ha-1. It was observed that with an increase in the nitrogen rate, the nitrogen uptake efficiency started to decrease. Haile et al. (2012) [21]reported that when different rates of nitrogen were applied to different varieties of soil, the highest nitrogen efficiency was observed at 30 kg ha-1 and the lowest at 120 kg ha-1. Combining these results, Moll et al. (1982)[42], Ortiz-Monasterio et al. (1997),[43] and Sinebo et al. (2004) [44] also reported that N uptake efficiency was higher at lower rates of nitrogen, but decreased significantly with increasing application rate of the nutrient.

Grain nitrogen uptake

Peter et al. (2019) found that grain nitrogen uptake generally increased with growth in nitrogen rate by 21% from application rates of 0 to 135 kg N ha-1. This result was in contrast to Arduini (2019),[46] who also observed that the highest grain N uptake was observed at 120 kg ha-1 and the lowest in the untreated experiment. This result was similar to that of Dereje et al. (2019),[47] who reported that grain N uptake was affected by the variety and application of nitrogenous fertiliser.

Application of more nitrogen than that required by wheat has less effect on grain nitrogen uptake because it propagates vegetative growth rather than during the reproductive period (Thenabadu, 1972).[48] Rodgers and Barneix (1988)[49] reported that wheat can differ in grain nitrogen uptake owing to differences in nitrate absorption.

Straw nitrogen uptake

The amount of N in straw is adversely affected by the application of nitrogen.[7] The highest content was observed at 120 kg N ha-1, and the lowest at 0 kg N ha-1. The increase in nitrogen concentration is due to the availability of sufficient nitrogen for shoot and root growth. A similar result was observed by Alemu et al., 2016,[35] who also stated that an increase in nitrogen application from 0 to 120 kg ha-1 increased the nitrogen content in the straw.

The results from the two sites reported by Lopez et al. (2005)[28] were inconsistent. Nitrogen rates of 90 and 132 kg ha-1 showed the same result as the nitrogen rate at 184 kg ha-1, and the nitrogen rates at 46 kg ha-1 and 92 kg ha-1 showed the same result. This was due to the

nitrogen application by split doses, which increased the straw nitrogen content by 93%.

Total nitrogen uptake

Total nitrogen uptake (grain and straw) was highest at a nitrogen rate of 120 kg ha-1 and lowest at a rate of 0 kg ha-1. Similar results were obtained by Fresew et al., 2018,[50] that the highest total nitrogen uptake (201.47 kg ha-1) was observed at a nitrogen rate of 360 kg ha-1 and the lowest at a nitrogen rate of 120 kg N ha-1. This result is similar to that reported by Amsal and Tanner (2001),[36] who reported the highest nitrogen uptake in a semi-dwarf variety at the highest nitrogen rate. In contrast, Moll et al. (1982)[42] reported no relationship between total nitrogen uptake and wheat variety.

Similarly, Motzo et al. (2004)[38] suggested that the highest nitrogen uptake by wheat is produced from the highest nitrogen applied. Thind et al. (2010)[51] suggested that most of the biomass yield and uptake was obtained owing to the proper application of nitrogen in the field. In general, most of the variation in total nitrogen uptake is due to differences in growth rather than differences in nitrogen concentration.[8]

The research conducted by Mishra (2024)[52] emphasizes the critical role of government investment in agriculture and policy recommendations to enhance agripreneurship and local economic development in Nepal. The study outlines that while Nepal has significant agricultural potential, challenges such as inadequate infrastructure, limited access to financial services, and insufficient market opportunities hinder agripreneurial growth.[52] Furthermore, Mishra, Nepal, and Aithal (2022)[53] discuss the implications of Industry 4.0 for Nepal's agricultural sector, advocating for the adoption of virtual farming technologies to improve efficiency and productivity. They highlight the necessity of integrating modern technological solutions to address traditional farming challenges. Additionally, Mishra (2024)[54] explores how fostering agripreneurship can stimulate local economies by creating jobs and enhancing food security. By implementing strategic investments in agricultural infrastructure and embracing innovative farming practices, Nepal can unlock its agricultural potential, ultimately leading to sustainable economic growth and improved livelihoods for rural communities. Investigating the impact of nitrogen rates on wheat grain yield, nitrogen content, and uptake is crucial for optimising agricultural productivity in Nepal. Research indicates that appropriate nitrogen application can significantly enhance wheat yields by improving both the quality and quantity of the grain produced, which should be enforced through recommendations.

Conclusion

In conclusion, the findings from the experiments underscore the critical role of nitrogen as an essential nutrient that significantly influences wheat grain yield, nitrogen content, uptake, and use efficiency. It is evident that while increasing nitrogen rates can enhance yield up to a certain threshold, excessive application leads to diminishing returns and potential negative effects such as lodging. This observation highlights the importance of tailoring nitrogen fertiliser applications to the specific requirements of the soil and the wheat variety being cultivated. Moreover, the study emphasises that optimal agronomic practices, including precise timing of nitrogen applications, are vital for maximising yield potential. The integration of these practices not only improves nitrogen use efficiency but also contributes to sustainable agricultural practices. Therefore, it is imperative for farmers to adopt a balanced approach to nitrogen management that considers both environmental impacts and economic viability. By implementing these strategies, wheat producers can achieve higher yields and improved grain quality while ensuring sustainable farming practices that benefit both the economy and the ecosystem in the long term.

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Conflict of interest

The authors declare no conflicts of interest.

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Data Availability Statement

No new data were generated or analyzed in support of this research.

Author Contributions Statement

Rajanish Mishra conceptualized the study. Methodology was developed by Rajanish Mishra. The original draft was written by Rajanish Mishra and Prashant Kumar Chaudhary and the manuscript was reviewed and edited by Rajanish Mishra. All authors have read and agreed to the published version of the manuscript.

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