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Effect of Nitrogen Application on Nitrogen use Efficiency indices and Yield at Heading under different Nitrogen Levels of Rice Genotypes

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ABSTRACT: The crucial role of nitrogen (N) in rice development emphasizes the potential of nitrogen fertilizer to increase yield. One key approach to maximize nitrogen use is the development of rice varieties with enhanced nitrogen use efficiency (NUE). The research specifically investigates the variations in genotypic physiological NUE and yield traits under different nitrogen levels. Under high nitrogen (HN) slit conditions, CRDhan 310 and Rasi showed increased nitrogen content compared to other genotypes. Notably, nitrogen use efficiency (NUE) increased with elevated nitrogen application at the heading stage in N22, Pusa44, and Vandana. However, there was no further increase observed at a higher nitrogen level than in HN. N22, especially when cultivated with nitrogen applied at an HN split level, exhibited higher Nitrogen Uptake Efficiency (NUpE) and Nitrogen Utilization Efficiency (NUtE). Nevertheless, as nitrogen levels and application increased, both uptake and utilization efficiencies decreased. Optimal grain production was achieved with a moderate level of nitrogen at the heading stage. Rasi stood out as it demonstrated the highest grain yield among genotypes under a moderate nitrogen (MN) split level. This finding suggests that a balanced and moderate approach to nitrogen application during the heading stage can lead to optimal grain production. This study provides valuable insights into how different rice genotypes respond to varying nitrogen levels. This knowledge is essential for developing more efficient and sustainable rice production practices, ultimately contributing to increased yields and environmental sustainability in agriculture.

Keywords: N Content, nitrogen utilization efficiency, Nitrogen uptake efficiency, yield, genotype, rice.

INTRODUCTION

The importance of rice (*Oryza sativa* L.) in the diets of billions of people across Asia, Latin America, and Africa cannot be overstated. With a significant portion of daily calories derived from rice, the demand for this staple is expected to surge by 50% by 2050 to sustain the growing global population. The provided passage highlights the challenges and imperatives of sustainable agriculture in the face of a rapidly growing global population. The focus is on the need to intensify agricultural productivity while concurrently safeguarding the environment, human health, and animal health. Within this framework, improving nitrogen use efficiency (NUE) is identified as a critical element (Zhang *et al*., 2015; Xiong *et al*., 2018). Nitrogen (N) is recognized as a vital component for the growth and development of plants, constituting a key element in all living cells (Marschner, 1995). Fertilizer N is highlighted as the second most significant requirement after water in crop production, and nitrogen deficiency is identified as the most common limiting factor for crop yields. The ratio of N taken up by a crop to the unit applied is defined as NUE (Fageria *et al*., 2014), where low N use may indicate inefficiency or an excess of uptake compared to the plant's requirements (Anas *et al*., 2020). Cereal crops such as rice, wheat, and maize are noted for their substantial N requirements, making varieties with higher NUE a priority for breeders developing new varieties (Balyan *et al*., 2016; Mălinaş *et al*., 2022). The passage provides global estimates of N stored in the soil, with a significant portion in the form of organic N, which is not directly available to plants (Batjes, 2014). Additional inputs of N come from chemical fertilizers, manures and biological N fixation (Fowler *et al*., 2013). It is mentioned that only 50% of applied N globally is converted, while the rest is wasted (Mălinaş *et al*., 2022). The discussion touches upon the two forms of plant-available N, ammonium (NH_4+) and nitrate (NO_3−). Factors influencing crop NUE are described as environmental conditions, plant physiological activity, and their interactions. The complexity of biochemical transformations of N in soil, in a state of continual flux, is emphasized as a major factor affecting NUE. Physical losses of N, such as volatilization of ammonia (NH_3) gas, leaching of dissolved nitrate (NO_3−), and overland runoff of all soluble forms, are highlighted as contributors to decreased NUE. In summary, the passage underscores the importance of addressing the nitrogen challenge in agriculture for sustainable and efficient food production, considering the intricate interplay of environmental, physiological, and biochemical factors in achieving improved NUE.

MATERIALS AND METHODS

A. Crop management

The experimental setup for a study on "Effect of nitrogen application on Nitrogen use efficiency indices and yield components at heading under different nitrogen levels of rice genotypes" conducted by the Department of Plant Physiology at the ICAR-India Agricultural Research Institute (IARI), New Delhi, during the 2018–2019 period. Nitrogen treatment was the primary plot factor for both seasons. Seven different genotypes were used as subplots. Each treatment consisted of three duplicated plots, each covering an area of 6 m^{-2}. Rice plants were grown in the nursery until they reached 25 days after planting. Soil samples were taken at a depth of 20 cm. The samples were collected in triplicate using an augur. The Kjeldahl method was employed to analyze the soil samples for nitrogen (N), phosphorus (P), and potassium (K). Urea, superphosphate, and potassium fertilizers were used for nutrient application. Urea was applied at a rate of 120 kg per hectare. Superphosphate was applied at a rate of 30 kg per hectare. Potassium fertilizers were applied at a rate of 40 kg per hectare. Urea was split into three dosages and applied during the heading stage

Table 1.

Heading stage	
Treatment	**Nitrogen (120kg/ha)**
Control	0 kg/ha
T1 (LN)	20 kg/ha
T2 (MN)	40 kg/ha
T3 (HN)	60 kg/ha

The data were subjected to statistical analysis using a split-plot design, following the approach outlined by Gomez and Gomez in 1984. Plant nitrogen content was determined using the Kjeldahl method, as specified by Yoshida et al. in 1976. Measurements were based on dry weight. Nitrogen Uptake Efficiency (NUpE) was calculated as the ratio of Total Plant nitrogen content to Nitrogen application rate. The formula used is NUpE = Total Plant nitrogen content / Nitrogen application rate. The efficiency is defined as the efficiency at which nitrogen is absorbed or supplied, citing Zoo *et al.* (2004). Nitrogen Utilization Efficiency (NUtE) was determined as the ratio of Grain weight to Total nitrogen in the plant. The formula used is NUtE = Grain weight/Total nitrogen in the plant. Utilization efficiency is defined as the efficiency of the whole plant nitrogen in rice production, citing Good *et al.* (2004). Various yield components were considered, including the number of siblings per plant, the number and number of grains per spike, and thousands of grains. The grain weight of each plant at maturity and seed yield were key parameters. Straw yield was expressed as dry weight.

Samples were dried to constant weight and hand-blended to determine yield, expressed in g $plant^{-1}$. Data processing and statistical analysis were carried out using a split-plot design, as specified by Gomez and Gomez (1984).

RESULT AND DISCUSSION

A. Shoot nitrogen content

Higher nitrogen content was found in all genotypes across different nitrogen levels, and the highest nitrogen content was observed as nitrogen levels increased (Fig. 1). Additionally, there's a specific mention of CRDhan310 and Rasi exhibiting higher nitrogen content when grown under nitrogen conditions at the HN cleavage stage compared to other genotypes.

B. Effect of application N on Nitrogen use efficiency (NUE)

The NUE of long-term genotypes CRDhan310, Rasi, and MTU1010 decreases when grown under nitrogen (N) conditions of the HN (High Nitrogen) split level (Fig. 4) This suggests that, under certain conditions, these genotypes may exhibit reduced efficiency in utilizing nitrogen. Rasi genotypes, however, showed enhanced NUE when grown at different N levels compared to levels with increased NUE. This indicates that Rasi genotypes may have a better nitrogen utilization efficiency under specific nitrogen conditions. The statement mentions several factors that could influence NUE, including the nitrogen efficiency of biomass production, the effect of N on carbohydrate distribution, nitrate-reducing activity, and the recycling of nitrogen from old tissue and storage (Foulkes *et al.*, 2009). Nitrogen uptake by rice genotypes at various times increases with nitrogen application but decreases nitrogen utilization efficiency (Liu *et al*., 2022.). This implies that while increased nitrogen application leads to higher nitrogen uptake, it doesn't necessarily result in proportional benefits in terms of efficiency. The Physiological Nitrogen Use Efficiency (PNUE) of all genotypes decreases with increasing nitrogen application rate. This suggests that the ability to increase yield per kilogram of pure nitrogen decreases as the nitrogen application rate increases.

The results align with findings from other studies, such as those by Li *et al*. (2012); Quanbao *et al*. (2007); Feng *et al*. (2011), which also observed that under high nitrogen conditions, lower PNUE ultimately led to lower NUE same were studied by Javad *et al*. (2022). The reduction in PNUE at higher nitrogen application rates indicates that rice plants may struggle to absorb or utilize nitrogen at a higher rate, or that the rate of nitrogen uptake by plants cannot keep up with the loss of nitrogen. The uptake of N by different duration rice genotypes increases with increasing the rates of N application, but it reduces the N use efficiency. It was observed that within creasing N application, the PNUE of all genotypes decreased significantly. It indicated that the capability of increase in yield per kilogram of pure nitrogen declined remarkably with increasing nitrogen application.

C. Effect of application of N on NUpE and NUtE

Determination of NUE helps distinguish the ability of genotypes and cultivars to both absorb and assimilate nutrients, leading to increased dry matter and yield. NUE is a critical parameter for assessing the efficiency of nitrogen utilization in plants. Short-term genotypes N22 and High-N of Vandana demonstrated strong nitrogen uptake efficiency (NUpE) and utilization efficiency (Fig. 2). These genotypes exhibited effective absorption and assimilation of nitrogen, contributing to increased dry matter production and yield same study was done by Zhang *et al*., 2019.The statement mentions that there was no significant difference in Nidi compared with the long-term genotype. This suggests that, in terms of nitrogen utilization efficiency, Nidhi performed similarly to the long-term genotype. Long-term genotypes MTU1010 and CR Ddhan 310 showed reduced efficiency at high nitrogen (HN) levels (Fig. 3). This implies that these genotypes may not perform as well in terms of nitrogen utilization under conditions of elevated nitrogen levels. No significant differences were observed among all genotypes at low nitrogen (LN) and medium nitrogen (MN) levels. This suggests that, under these nitrogen conditions, the genotypes performed similarly in terms of nitrogen uptake and utilization. Similar studies were reported by Ma *et al*. (2023). In summary, the information highlights the variability in nitrogen utilization efficiency among different genotypes and how this efficiency can be influenced by nitrogen levels. Short-term genotypes, such as N22 and High-N of Vandana, demonstrated strong nitrogen uptake and utilization efficiency, while certain long-term genotypes exhibited reduced efficiency at high nitrogen levels. The comparison of genotypes across different nitrogen levels provides valuable insights into their performance under varying nutrient conditions. This might depend on the nitrogen efficiency of biomass formation, the effect of Noncarbohydrate partitioning, nitrate reduction efficiency, and the remobilization of N from senescent tissues and storage functions (Foulkes *et al*., 2009).

D. Effect of application of N on yield

Grain yield increased when growing in different N. The short-term genotype N22 showed a higher yield at the level of HN cleavage with nitrogen fertilization. Long term Rasi genotypes were found to produce more grains when treated with N at the MN cleavage stage (Fig. 5). Using split N in expression showed better results compared to other N levels in the medium. More N applications will result in lower yields when planted at different N levels. Grain yield increased when grown under different nitrogen levels. This suggests that nitrogen fertilization positively influences the production of grains. The short-term genotype N22 exhibited a higher yield at the HN (High Nitrogen) cleavage level with nitrogen fertilization. This implies that N22 is more responsive to increased nitrogen levels, leading to improved grain yield. Long-lived Rasi genotypes were found to produce more grains when treated with nitrogen at the MN (Medium Nitrogen) cleavage stage. This indicates that the timing of nitrogen application can influence grain yield in long-term genotypes like Rasi. Using split nitrogen application showed better results compared to other nitrogen levels in the medium. This suggests that a staggered or split application of nitrogen may be more effective in promoting grain yield compared to other nitrogen application methods or levels in medium nitrogen conditions. The results of the present study are supported by the findings of Zhang *et al*. (2022). The statement indicates that more nitrogen applications will result in lower yields when planted at different nitrogen levels. This is consistent with the concept of diminishing returns, where the incremental benefit of additional nitrogen diminishes as the application rate increases. In summary, the information highlights the nuanced relationship between nitrogen levels and grain yield in different genotypes Gu and Yang (2022). It underscores the importance of considering both the specific genotype and the timing/method of nitrogen application to optimize grain yield. Additionally, it suggests that there is an optimal range for nitrogen application, and excessive nitrogen may lead to diminishing returns in terms of grain yield (Guo *et al*., 2022).

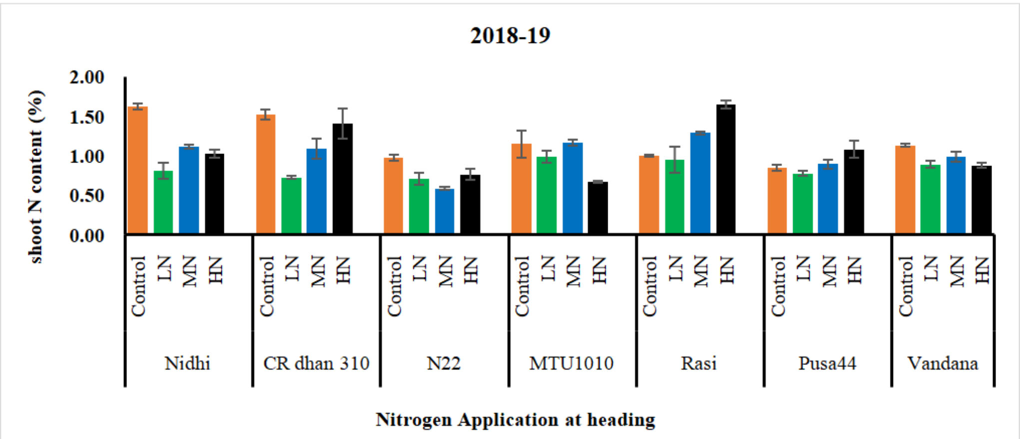

Fig. 1. Effect of nitrogen application at heading on shoot N content.

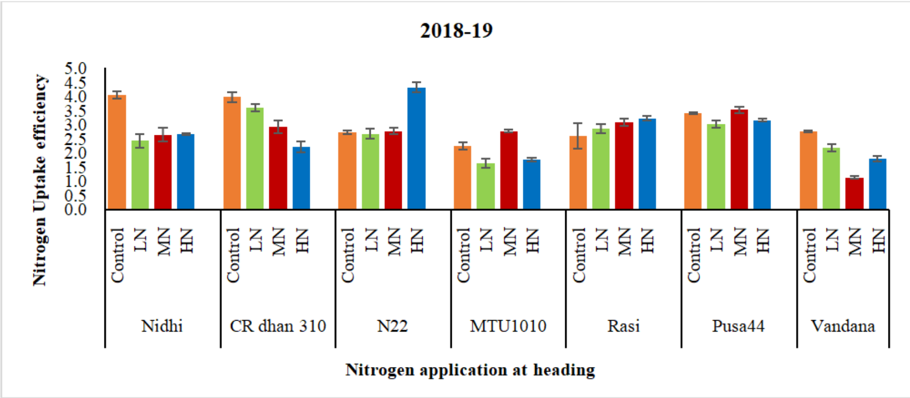

Fig. 2. Effect of nitrogen application at heading on Nitrogen Uptake Efficiency.

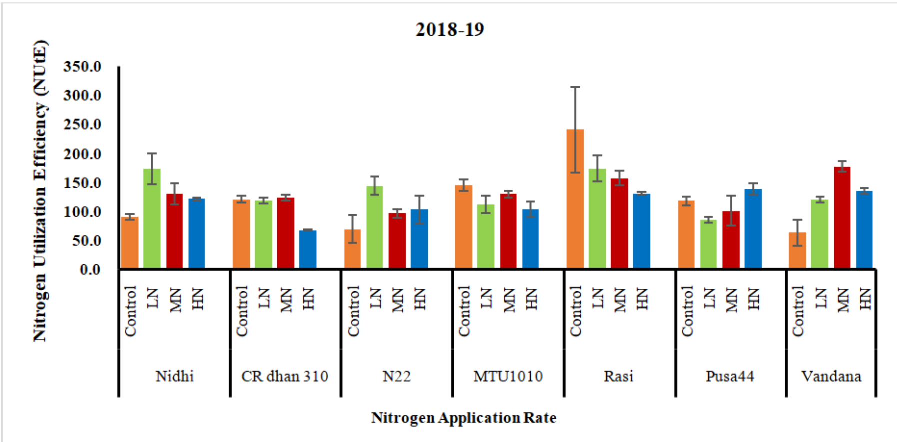

Fig. 3. Effect of nitrogen application at heading on Nitrogen Utilization Efficiency.

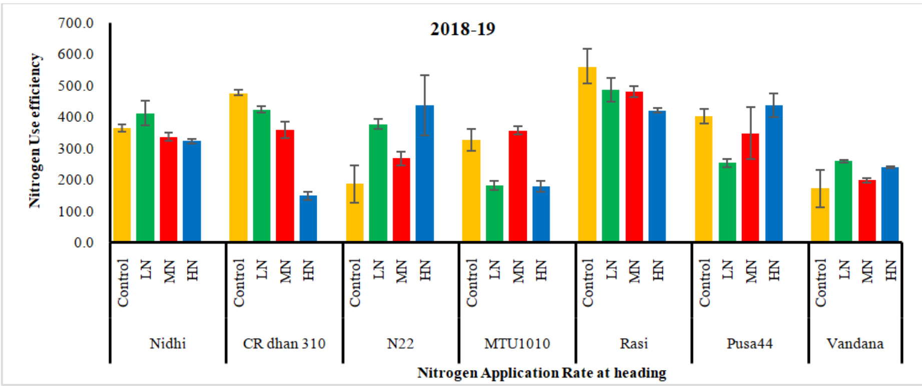

Fig. 4. Effect of nitrogen application at heading on Nitrogen Use Efficiency.

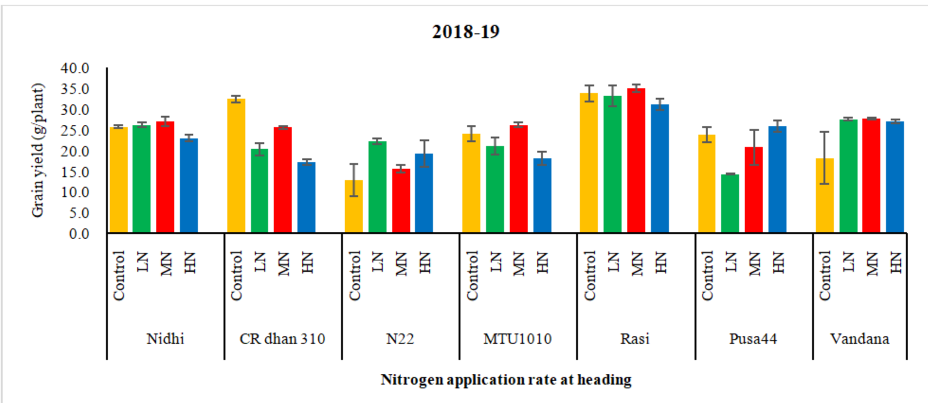

Fig. 5. Effect of nitrogen application of Nitrogen at heading on Grain yield.

CONCLUSIONS

The importance of nitrogen levels in influencing the nitrogen content in plants, particularly in rice genotypes such as CRDhan310 and Rasi. It emphasizes that these genotypes may have a higher nitrogen uptake or utilization capacity during the HN cleavage stage. The complex relationship between nitrogen levels, nitrogen utilization efficiency, and various physiological factors affecting nitrogen uptake in rice genotypes is acknowledged. The findings suggest that optimizing nitrogen application is crucial for maximizing yield while ensuring efficient use of nitrogen. The variability in nitrogen utilization efficiency among different genotypes and how this efficiency can be influenced by nitrogen levels is a key consideration. Short-term genotypes like N22 and High-N of Vandana are noted for strong nitrogen uptake and utilization efficiency, while certain long-term genotypes show reduced efficiency at high nitrogen levels. The comparison of genotypes across different nitrogen levels is highlighted as providing valuable insights into their performance under varying nutrient conditions. It emphasizes the importance of considering both the specific genotype and the timing and method of nitrogen application to optimize grain yield. The statement suggests that there is an optimal range for nitrogen application and that excessive nitrogen may result in diminishing returns in terms of grain yield.

FUTURE SCOPE

This information is essential for farmers and researchers alike, as it underscores the need for a nuanced approach to nitrogen management in rice cultivation for optimal results.

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Conflict of Interest. None.

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