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Physiochemical characterization of rice genotypes based on gel consistency and alkali digestion under different N levels

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Abstract
One crucial agronomic tool for regulating grain quality is nitrogen fertilizer. However, the impact of nitrogen application on grain quality during heading has not been well studied. Grain quality parameters, such as Gel Consistency (GC) and Alkali Digestion Value (ADV) responses to nitrogen fertilizer were determined in a field experiment. We found that GC and ADV decreased as the nitrogen application level at the heading stage. When considered collectively, our findings showed that GC and ADV increase in Pusa 44 in response to an elevated nitrogen content at the heading.

Keywords: Physiochemical characterization, rice genotypes, gel consistency, alkali digestion, Nitrogen

1. Introduction
Rice (*Oryza sativa* L.) is a monocotyledonous plant in the genus Oryza and family Gramineae, which is closely related to grass. For nearly 23 percent of the daily calorie requirement, rice is the primary staple food consumed by 57% of the world's population (Vijay *et al*., 2013) [14]. In rice grain quality is a complex feature that can be affected by several variables, including genetic composition, environmental factors, and agricultural techniques, of which nitrogen (N) fertilization is a key component (Koutroubas *et al*., 2004) [7]. A vital component of plant growth, nitrogen directly influences the processes of photosynthesis, protein synthesis, and metabolism. These processes in turn affect grain production, size, shape, and nutritional value (Morales *et al*., 2020) [10]. An essential part of amino acids, which are the building blocks of proteins, is nitrogen. As a result, rice grains with nitrogen fertilization often have higher protein content. On the other hand, a high protein level could negatively impact the cooking quality, resulting in less sticky and tougher rice.
The impact of nitrogen (N) application on gelatinization temperature (GT) and gel consistency (GC) in rice genotypes demonstrates the complex interplay between agronomic practices and the physicochemical characteristics of rice grains, which in turn influence cooking and eating quality (Shah *et al*., 2024) [12]. Critical factors in assessing rice quality are both GC and GT, which have an impact on customer preferences and processing attributes (Saquee, *et al*., 2023) [11]. Rice's processing and cooking properties can be impacted by nitrogen due to its ability to change the temperature at which starch gels and its gel consistency (Xiong *et al*., 2022) [16]. While the precise correlation between nitrogen fertilisation and grain index (GI) remains unclear, variations in the levels of amylose and amylopectin resulting from nitrogen fertilization may impact rice GI (Guo *et al*., 2023) [3]. Optimizing grain quality requires an understanding of genotype-specific responses to nitrogen. Rice varieties with optimal nitrogen usage efficiency are developed and recommended by agronomic procedures and breeding programs to produce high yield and quality with the least amount of negative environmental impact (Aguirrezábal *et al*., 2015) [1]. Precision agriculture techniques, such as site-specific nitrogen management (SSNM), can help tailor nitrogen application to the specific needs of different rice genotypes, thereby maximizing grain quality and minimizing negative environmental effects (Ali *et al*., 2020) [2].

The effect of nitrogen (N) application on gel consistency (GC) and gelatinization temperature (GT) in rice genotypes highlights the intricate relationship between agronomic practices and the physicochemical properties of rice grains, which ultimately affect cooking and eating quality (Lou *et al*., 2023) [9]. By adjusting nitrogen treatment to the unique requirements of various rice genotypes, precision agricultural techniques like site-specific nitrogen management (SSNM) can assist maximize grain quality and reduce adverse environmental effects (Ali *et al*., 2020) [2]. The relationship between agronomic practices and the physicochemical properties of rice grains which ultimately affect cooking and eating quality is highlighted by the effect of nitrogen (N) application on gel consistency (GC) and gelatinization temperature (GT) in rice genotypes (Lou *et al*., 2023) [9]. When assessing the quality of rice, both GC and GT are important factors that affect customer preferences and processing attributes. In conclusion, there is a trade-off between yield, appearance, cooking qualities, and nutritional content in the complicated and genotype-dependent interaction between nitrogen treatments and rice grain quality. Comprehending soil fertility, plant feeding concepts, and rice genetics in great detail is necessary to achieve the ideal equilibrium.

2. Materials and Methods

Seven nitrogen-use efficient rice genotypes of short duration (113 days) viz. Nidhi, MTU1010, N22, and Vandana. Long duration (130 days) viz, CR Dhan 310, Rasi and Pusa44 selected from a previous study in the Division of Agronomy, ICAR-IARI were evaluated in the field during the Kharif seasons of 2018 and 2019 at the Indian Agricultural Research Institute, New Delhi. All these high nitrogen use efficient genotypes showed a maximum grain yield of more than 0.2 kg/ha of seeds under 120 kg/ha of N.

2.1 Crop husbandry

The experiment spanned kharif seasons 2019-20. Seeds were sown on June and 25 days old seedlings of all genotypes with similar growth were selected and transplanted. The experiment followed a split-plot design where Nitrogen (N) treatment was used as the main plot and the genotypes were used as subplots. Three replicate plots of 6 m² were used for each treatment. Urea (120 kg ha^{-1}), single superphosphate (30 kg ha^{-1}), and potash murate (40 kg ha^{-1}) were applied as nitrogen (N), phosphorus (P), and potassium (K), respectively. Potash fertilizer (K_2O) was applied as a basal dose at active tillering, panicle initiation, and heading stage, detailed treatments given on Table 1. Phosphorus was applied as P2O5 in the form of SSP @ 60 kg $ha^{-1,}$ and potassium was applied as K2O in the form of murate of potash @ 40 kg ha^{-1} at transplanting. By agricultural and management standards, split doses of nitrogen were administered at the several growth phases listed below (Table 1). Samples of plants and grains were taken at the heading and maturity stages to analyse the Gel consistency (GC) and Alkali Digestive Value (ADV).

Table 1: Nitrogen treatments at different growth stages

Nitrogen level (120 kg/ha)				
Stages	**Control**	**T_1**	**T_2**	**T_3**
Tillering	40 kg/ha	40 kg/ha	40 kg/ha	40 kg/ha
Panicle initiation	80 kg/ha	20 kg/ha	40 kg/ha	60 kg/ha
Heading	0 kg/ha	60 kg/ha	40 kg/ha	20 kg/ha

2.2 Gel consistency

A palm dehusker was used to remove the husks from the rice grains during the dehusking process. An electric mill was then used to ground the dehusked rice grains into rice flour. 500 mg of rice flour, or rice powder was weighed for each rice genotype. The 0.025% thymol blue solution and 0.026 ml of 95% ethanol were mixed and added to the rice powder. The mixture was then added with 2 ml of 0.2 N KOH and the tubes containing the mixtures were then heated to 92 °C for 6 min. After boiling, the glass caps were placed on the tubes and they were allowed to cool for five minutes. After that, the tubes were put in tubes, the tubes were immersed in ice for 15 min. After settling the gel for 30 min, the tubes were set up horizontally on graph paper and the length of the gel was measured in mm from the bottom of the tube to the bottom of the gel.

2.3 Gelatinization temperature (Alkali Digestion Value)

Within a Petri plate with 20 ml of 1.7% KOH, twenty-five dehusked grains were evenly distributed in three replicates in each of the four treatments. On a 7-point scale, the grains' spreading and clearing values were noted. Due to the inverse relationship between gelatinization temperature and score, grains with low scores at high temperatures did not completely disintegrate, whereas grains with high scores at low temperatures disintegrated.

3. Results

The analysis of variance suggested there was a significant effect (P-Value < 0.05) for genotype, treatment, and genotype x treatment interaction for gel consistency. The dose response was more evident in short duration genotypes, though it was not consistent. Nidhi and MTU 1010 exhibited an increase in gel consistency with increasing N application at heading whereas N22 and Vandana showed an opposite trend. Among the long duration genotypes, Rasi did not show any variation with different N doses, while CR Dhan 310 and Pusa 44 displayed an opposite pattern at MN and HN doses compared to control. CR Dhan 310 showed 25 and 12 % reduction at MN and HN respectively whereas Pusa 44 showed higher (16%) increase with MN and HN over control N (Fig 1)

Based on the degree of alkali digestion observed (Figure 2), the rice genotypes were classified into three groups; low, intermediate, and high alkali digestion values. Among all the genotypes with low degrees of alkali digestion value recorded in MTU1010 and Vandana when treated with all different levels of N. Nidhi, CRDhan310, Rasi, and Pusa44 showed higher alkali digestion values with higher levels of N. Lowest alkali digestion were observed in Vandana when grown under the high level of N. Among the N levels high N level showed high alkali digestion value. In general, all the short-duration genotypes showed low alkali digestion value (ADV) with a few exceptions like MN and HN treatments of Nidhi, MN of N22, and LN of Vandana, where ADV increased above the control. ADV values were high for long-duration cultivars and MN and HN treatments increased the ASV values in all three genotypes.

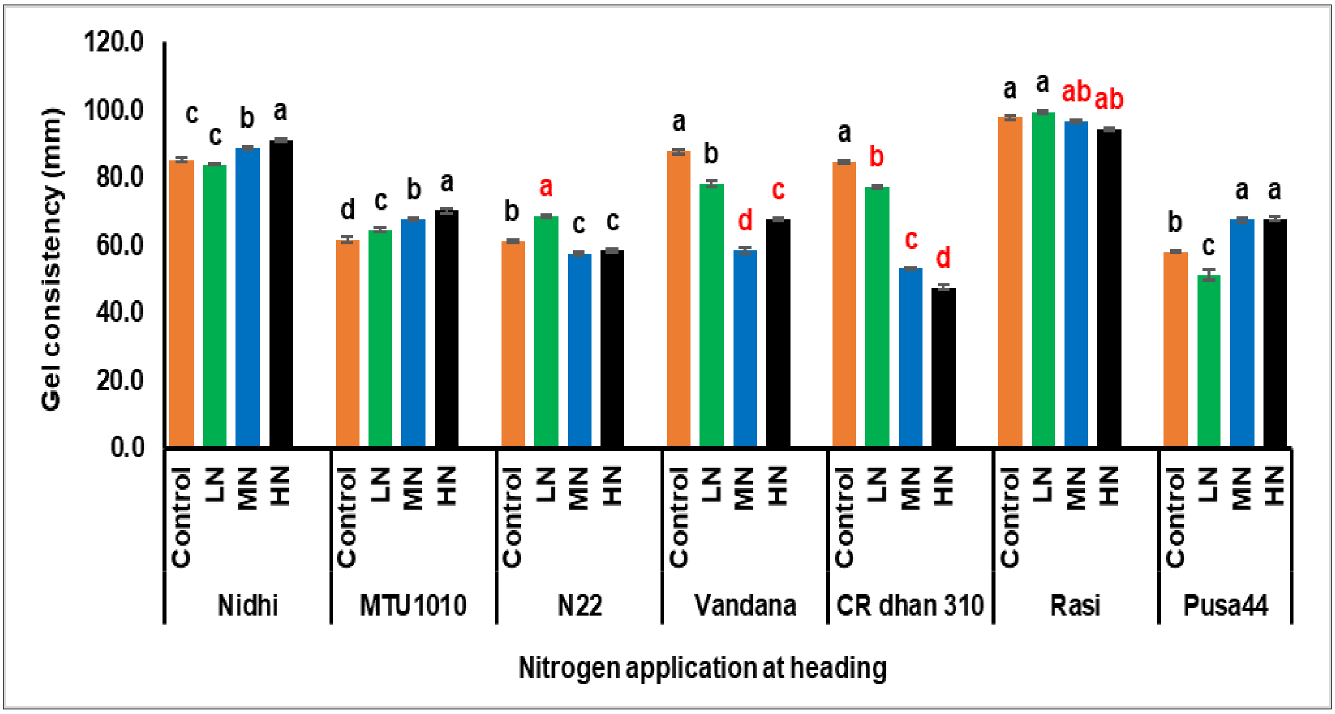

Fig 1: Effect of nitrogen application at heading on gel consistency (mm) in the rice genotypes. LN=low nitrogen, MN= medium nitrogen, HN=high nitrogen. Values are the means of three replications. Error bars represent ± SE (n=3). G =***, N =***, GxN= ***

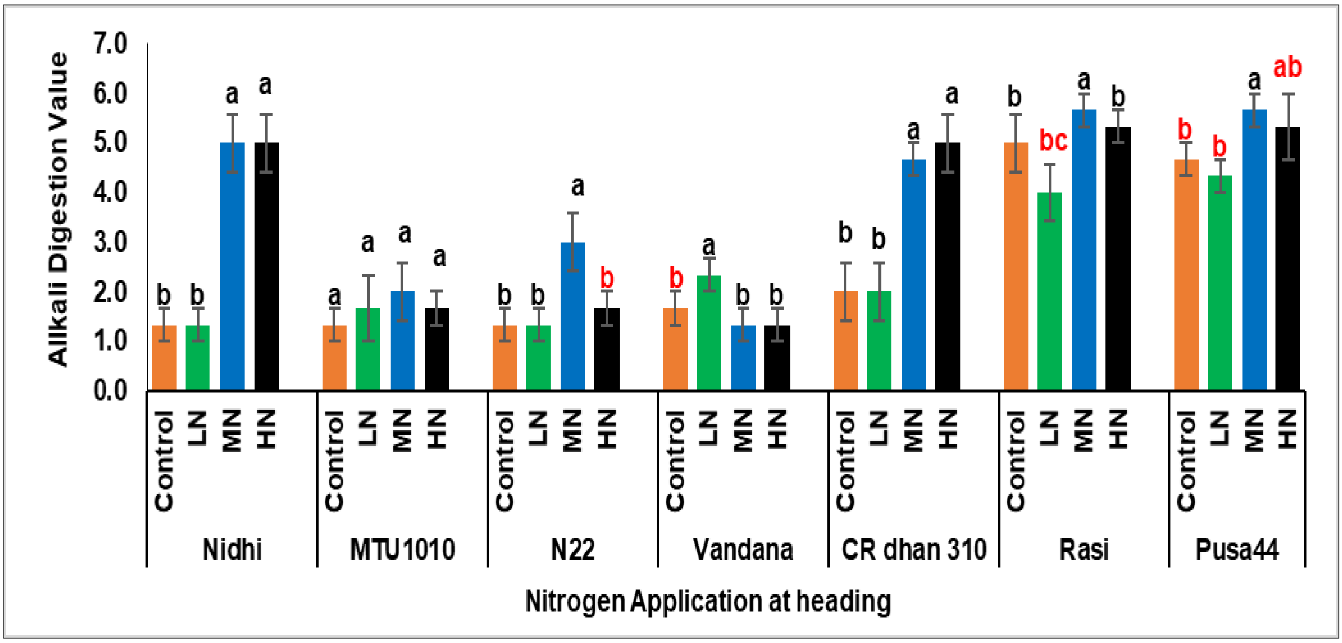

Fig 2: Effect of nitrogen application at heading on alkali digestion value in the rice genotypes. LN=low nitrogen, MN= medium nitrogen, HN=high nitrogen. Error bars represent ± SE (n=3). G =***, N =***, GxN= ***

4. Discussion

Alkali digestion is one of the important indicators of the eating, cooking, and processing quality of rice starch (Zhao *et al*., 2022) [19]. In this study, the determination of the alkali digestion classified the rice genotypes into three groups namely; low, intermediate, and high alkali digestion. Similar classifications have been reported in HaL rice cultivars (Yin *et al*., 2007) [17]. In this study, lower alkali digestion values were observed when treated with LN levels indicating that the lower application rate of nitrogen could be attributed to the presence of more long amylopectin chains (B2 and B3) than the short (A and B1) amylopectin chains (Yin *et al*., 2013) [18]. The activity of the SSIIa is higher in the low alkali digestion cluster than in other classifications which increases the proportion of the short amylopectin chains (Hu *et al*., 2009) [4]. Given that there is an inversely proportional relationship between the alkali digestion value and the gelatinization temperature, the genotypes with low alkali digestion have a high gelatinization temperature.

The rice grains that were highly affected by the alkali solution had a high ADV due to the presence of amylopectin with a high number of short chains (A and B1) and with minimal number of long amylopectin chains. The SSIIa activity is maximal amongst these genotypes since this gene plays a vital role in the elongation of the short amylopectin chains (Zhu *et al*., 1988) [21]. The same results were observed when treated with an HN level of nitrogen indicating that an increased nitrogen level increases the short chains of amylopectin with minimal long amylopectin chains.

The gel consistency test was developed as an indirect method used in screening cooked rice for its hardness, especially in rice with high amylose content (Wang *et al*., 2020) [15]. This physicochemical test is used in rice improvement programs to ascertain if high amylose genotypes are soft or hard textured when cooked (Tao *et al*., 2019). In this study, genotypes were classified into soft, intermediate, and hard GC based on the gel consistency values (Ishimaru *et al*., 2003) [5]. The three classifications could be a result of different expression levels of the waxy gene and the variations in the Wx gene locus (Zhu *et al*., 2017). Genotypes with soft GC had a gel length that was more than 61 mm. This physiochemical trait was observed in most of the rice genotypes under study and showed that increased nitrogen level at the heading stage has increased the GC values indicating that hard gel consistency which occur as a result association of starch polymers in the aqueous phase. Amylose polymers leach when the starch granules are heated and they subsequently form networks once the gel cools (Ju *et al*., 2011; Liang *et al*., 2015) [6, 8].

5. Conclusion

The study revealed nitrogen application level significantly affected the grain quality of rice. In this study, we found that the quality parameters GC and Alkali digestion value increases when the nitrogen application rate with HN level at heading and this also suggested that the High nitrogen application (60kg N/ha) at heading improved grain quality in rice.

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7. Reference

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