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Evaluation of wheat (*Triticum aestivum*) genotypes for higher yield and enhanced nitrogen use efficiency in Muzaffarnagar

Sachin Kumar, Ankit Kumar, Divya Patiyal and Ashu

Shri Ram College, Circular Road, Muzaffarnagar, India

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Abstract

Extensive research has been conducted on various nitrogen(N) management approachest of ulfil the growing needs of cereals while enhancing the efficiency of agricultural resource eutilization .Never the less, the intensive agricultural model continues to prioritize the achievement of high crop yields and improving nitrogen use efficiency(NUE)as opposing targets. The primary aim of this study wasto investigates whether a corresponding increase in N application is necessary to achieve higher crop yields. The study evaluated the effects of 3N treatments (N0,N75,andN150) on 10 wheat (*Triticum aestivum* L.) genotypes during 2022–23and 2023–24 at research farm of Shri Ram College, circular Road, Muzaffarnagar.In both growing seasons, the highest grain yield (GY) of 5.3 t/ha, agronomic efficiency (AE_N) of 28.7 kg grain/kg N,and partial factor productivity of applied N(PFP_N) of 60.2kg grain/kgN were obtained by the HD3249 genotype, followed by HD3117.

The application of N75and N150 increased grain yields by 72.3 and 142.6% ,respectively ,over N0. Significant relationships were observed between GY,PFP_N and AE_N at all N levels, and a decreasing trend was observed in both PFP_N and AE_N as the N application rate increased. The study results suggest that the adoption of genotype-specific nitrogen(N) rates could provide a mutually beneficial solution to meet the growing demand for food while improving NUE. Over all ,based on GY and AE_N ,there search findings indicate that the genotypes HD3249 and HD3117 are efficient candidates for N use,with the potentiall for higher yield sand NUE in the Muzaffarnagar of India.

Keywords: Genotype-nitrogen rates, Grain yield, Nitrogen management, N-use efficiency, Wheat genotypes

Introduction

The excessive use of nitrogen (N) in cereal crops is a global phenomenon. However, the low N recovery efficiency in cereals, which is less than 35%, has raised concerns due to the severe negative environmental consequences caused by the remaining N (Raun and Johnson 1999, Hirel *et al.* 2007,Xu*etal.*2012).To address these challenges, a potential option is to increase productivity by adopting cultivars that have good genetic potential for N use (Reynolds*etal.*2012). One of the best approaches to achieve the objective of high production of wheat (*Triticum aestivum* L.) is to improve crop yields on existing farm land with suitable genotypes. Unfortunately, over the past 20 years, the rate of increase in economic yield of wheat is only 0.9% per year (Ray *et al.* 2013).

***Corresponding Author**

To achieve higher wheat yields, the crop must meet the high N requirements, which typically leads to proportional increase in N fertilizer usage. Mueller *et al.* (2012) stated that 9% increase in the use of N fertilizers would be needed to bridge the yield gaps of the main cereals (rice, wheat, and maize) and achieve a 30% increase in production in the coming decades. It remain sun clear whether this conclusion is relevant to wheat cultivation in India, where farmers use excessive N fertilizer to achieve high grain yields, resulting in decreased nitrogen use efficiency(NUE). More field research is needed to evaluate the possibility of boosting crop yield and whether it necessitatees a proportional increase in N fertilizer application.

The regions of India with high wheat production have them ost intense application of N in the country. It is possible to decrease the fertilizer N usage while maintaining high grain yield and enhancing NUE through genotypes that have genetic potential to high N absorption and assimilation (Tian *et al.* 2018, Wang *et al.* 2012a, Wang *et al.* 2012b). So, still large gaps area vailable to compares various N rates for different genotypes to enhance both yield and NUE. Therefore, this study was carried out to assess the various N inputs on winter (*rabi*) wheat for determining optimal N rate, yield and NUE.

Material and Methods

The research experiments were conducted during 2022–23 and 2023–24 at the research farm of Shri Ram College, circular Road, Muzaffarnagar. The field weather was characterized by cool and temperate. The average maximum and minimum temperatures recorded in the regions ranged between 17–38°C and 7–17° respectively. Moreover , the mean precipitation during cropping season is 181.5 mm.

Experimental design and crop management: The experiment involved 3 different nitrogen treatments (main plot) and10 wheat genotypes (HD-3226,HDCSW-18,HD-2967,HD-3086,HD-3249,HD-2733,PBW-550,PBW- HD-3117, HD-3298-subplot) that were assigned to plots in a split plot design. The 3N-rate treatments included N0 (no nitrogen-NN), N75 (75 kg N/ha low nitrogen-LN) and N150(150kgN/ha- high nitrogen-HN).Before sowing, basal fertilizers such as phosphorus (60 kg P_2O_5/ha) and potash (60kgK_2O/ha)were applied, while nitrogen was applied in 3 separate splits. Half of the nitrogen was applied as basal, 1/4thduring the crown root initiation stage [20–25 DAS(days after sowing)], and the remaining 1/4thduring the tillering stage (40–45 DAS). The fields were irrigated 6 times by flood irrigation. The effects of the 3N treatments on wheat genotype yield and nitrogen use efficiency (NUE) were analysed and compared between the different genotypes.

Sampling: After reaching maturity, 3–4 m^2 areas in each plot were used for manual harvesting, threshing and measurement of yield. Subsequently, the grain was dried to a constant weight in an oven set at70°C and maintained a moisture content of 12.5% in the grains.

Calculation of N-use efficiencies: The N-use efficiencies (agronomic efficiency-AE_N and partial factor productivity- significantly reduced PFP_N under both LN and HN.

The HD3249 and HD3117 genotypes out performed other genotypes in terms of the response to grain yield (GY) at all levels of N (NN,LN,HN) (Fig1 and Table1).On average, the maximum GY for HD 3249 and HD 3117 was 5.3/t ha and 5/t ha, respectively. Genotype HD 3226 yielded the lowest at 2.7 t/ha, while all genotypes responded up to the N level N120, although with varying grain yield results (Fig1). Selecting genotypes that are suitable for specific areas, based on soil fertility and weather conditions, is crucial to improving both GY and nitrogen use efficiency PFP_N) were calculated.

Data Analysis: Statistical analysis of all data was performed using the open-source available statistical software R Studio [agricolae package of R Version (Mendiburu 2021)]. For comparisons of multiple means Duncan’s method are used, with an alpha probability level of 0.05. The 'performance analytics' packages in R studio (2021) were used to create a Pearson's correlation coefficient matrix or diagram, utilizing the recorded crop traits data spanning over two years.

Results and Discussion

Grain yield and NUE under 3 N levels**:** Over 2 years, N rate, and genotypes significantly influenced the yields (Table 1, Fig 1). Genotypes grown under N150 (HN) had a significantly higher average yield (5.92 t/ha) than those grown under N75 (LN) (4.21 t/ha) and N0 (2.44 t/ha) across both years. The N levels LN and HN had mean yield increases of 72.3% and 142.6%, respectively, compared to N0 (NN) (P<0.05). AE_N was comparable between LN and HN, but $PFP_N$was significantly higher at LN than HN (P<0.05)(Table2). Furthermore, the increase in N(NUE), thus reducing the negative effects of N fertilizers. The calculated average optimal N rate for wheat genotypes was 150 kg N/ha to achieve maximum GY.

Factors driving maximum yield and high NUE:

For determination of LN and HN rates effects on wheat NUE, PFP_N and AE_N values were correlated with GY. Pearson's correlation analysis revealed highly significant positive correlation between grain yield, AE_N and PFP_N at mean levels of N, as well as LN and HN (P<0.001), and significant correlation between the mean N yield and partial factor productivity (PFP) at P<0.01.

A significant area of focus in modern agricultural research is to improve NUE without sacrificing wheat yield by reducing N application. Genotypes HD 3249 and HD 3117shows higher wheat GY highlights the importance of their high yield potential under the same levels of N, making them more suitable choices in all aspects compared to other genotypes. In this study, the use of appropriately adapted cultivars with optimal N rates showed potential to improve the available N uptake and increase the plant N conversion to GY .Our findings match with Voss-Fels *et al* .(2019), who reported that optimal N rate sand genotypes with high genetic potential for NUE could improve winter wheat yields. The findings of Hameed *et al*. (2019) also support our results, indicating that selecting the appropriate dose and cultivar of N can reduce N losses, providing a chance to decrease N application while improving NUE. In fact, genotype-specific N management played a crucial role in determining NUE research is to improve NUE without sacrificing wheat yield by reducing N application. Genotypes HD 3249 and HD 3117shows higher wheat GY highlights the importance of their high yield potential under the same levels of N, making them more suitable choices in all aspects compared to other genotypes. In this study, the use of appropriately adapted cultivars with optimal N rates showed potential to improve the available N uptake and increase the plant N conversion to GY .Our findings match with Voss-Fels *et al* .(2019), who reported that optimal N rate sand genotypes with high genetic potential for NUE could improve winter wheat yields. The findings of Hameed *et al*. (2019) also support our results, indicating that selecting the appropriate dose and cultivar of N can reduce N losses, providing a chance to decrease N application while improving NUE. In fact, genotype-specific N management played a crucial role in determining NUE. For example, based on the pooled analysis data, genotype HD 3249 shows an average PFP_N of 60.2 kg/kg and AE_N of 28.7kg/kg. Similar results were reported by Good *etal* . (2011), who found that the genetic potential of a genotype significantly influences the improvement of NUE. The greater efficiency of N use observed in certain genotypes may beat tribute to the effectiveness of their root systems in efficiently utilizing available N resources (Cassman *et al*. in 2002). Among the nitrogen levels tested, N150 shows highest NUE and GY. This could be reason behind the genetic makeup of the selected genotypes, which have the inherent ability to respond more effectively to higher levels of N (Duan *et al*. 2020).A key strategy to improve both wheat GY and NUE is to adopt cultivars that are well adapted region-specific weather conditions. Myagkikh *et al*. (2021) support this notion, stating that selecting a cultivar that is adaptable to the agroclimatic conditions of a particular region is a primary approach to generatest able grain yield with desired quality characteristics. Therefore, it is important to evaluate cultivar performance at various agronomic research centres.

The application of HN does not always result in higher crop yields, as the law of diminishing returns suggests (Cassman *et al*. 2002), leading to reduced NUE in crop production systems. This study revealed that N levelsN75 and N150 increased the GY of all genotypes by 72.3 and 142.6%, respectively, compared to N0. Optimizing the timing and rates of nitrogen (N) fertilizer application in agriculture can not only increase crop yields but also minimize N loss to the environment (Liu *et al*. 2019).

Based on the results, it can be observed that the GY of the genotypes exhibited a positive correlation with the N levels applied until the highest N rate was reached in the 3N treatments

(Fig2).Under field conditions, farmers frequently apply excessive amounts of N fertilizer to crops for achieving high yield per unit area, despite the inherent in efficiencies associated with this practice and different genotypes (Cui *et al.* 2008a, 2008b). Furthermore, a lack of knowledge regarding the appropriate N application rate often leads farmers to apply excessive N to prevent low crop yields(Zhang*etal.*2011).Based on our findings ,the ideal N rate for the genotypes HD 3249 and HD 3117 was 150kgN/ha, suggesting that farmers can achieve their yield targets and improve NUE by reducing N fertilizer input while following this recommendation .Therefore, location- specific genotype selection and N application rates must be taken into account to enhance agricultural production performance. (Cai *et al.* 2021).

The N0 plot yield indicates the performance of genotypes under conditions of no external N supply and the nutrient supply capacity of soil (Cui *et al.* 2008a,Wang *et al.* 2012a, Wang *et al.* 2012b). This suggests some of the potential for higher yields in the NN genotype compared to LN and HN .Similarly, positive correlations between wheat GY and various levels of nitrogen input were reported by Valkama *etal* .(2013)and Gaudin *etal* .(2015). The findings of this study indicate that the selection of genotypes that exhibit high GY and NUE at equivalent levels of N is critical in identifying superior genotypes .As the N rate increased, PFP_N and AE_N exhibited a decreasing trend. This statement agrees with Rahimizadeh *et al.* (2010), who reported a reduction in NUE with increasing N rate.

The present investigation has identified genotypes HD 3249 and HD 3117 with N150-splits having high yield and NUE in Muzaffarnagar, Uttar Pradesh India. The findings of this study support the notion that the cultivation of locally adapted cultivars can optimize grain yield while minimizing the negative environmental impacts arising from excessive nitrogen loss. Consequently, the adoption of such cultivars is recommended. Effective dissemination of scientific knowledge to farmer sand timely application of appropriate dose of N dosages with the right genotype are recommended to improve wheat yield and NUE in the future .Furthermore, these genotypes are important to utilize for breeding purposes. To ensure food security and prevent the adverse environmental impacts resulting from excessive N loss due to external N applications, it is imperative to adopt a vital strategy that involves achieving sustainable crop growth and enhancing NUE in farmer fields

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