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Interactive effect of Nitrogen and Phosphorus nutrition on Nitrogen use efficiency and crop productivity in wheat varieties (*Triticum aestivum* L. & *Triticum durum* L.)

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ABSTRACT: A field study was conducted in Vertisols of subtropical area of Central India. The major goal of the experiment was to compare the grain yield and other characteristics of selected wheat genotypes grown under various nutrient doses to determine which genotype outperformed the others. In the current study, nine different genotypes of wheat (*T. aestivum* and *T. durum* L.) were chosen and cultivated as experimental crops. A split plot design, which was replicating three times, was used, with nutrient dose serving as the main plot and the other wheat varieties serving the sub-treatments. There are 36 plots in a block in each of the following treatments: T1 was control, T2 was 100% (N+P+K), T3 was 50% N+100% (P+K), and T4 was 50% P+100% N+K. The HI 8713 variety had the highest rate of total nitrogen uptake, and it also had the highest quantity of grain yield, demonstrating a direct correlation between nitrogen uptake and grain yield 7. HI 1563 showed the highest apparent recovery of N (95.96%) under low doses of N, followed by GW366 (88.13%). GW366 had the highest average Agronomic Efficiency (20.05%) across all fertilizer N doses. Variety Narmada 14 had the highest Physiological Efficiency (60.63%) under standard N circumstances, followed by HI 1531, or 59.13%.2. The variety HI 8713 of wheat exhibited significantly higher biomass, grain yield, nitrogen content in grain and straw, total nitrogen uptake, and agronomic use efficiency by N than any of the other evaluated wheat varieties. Agronomic use efficiency, perceived nutrient recovery, and physiological efficiency-all measures used to describe use efficiency-were extremely variable depending on genotypes and application rates for N and P.

Keywords: Nitrogen use efficiency, Nitrogen, Nutrient recovery, Agronomic Efficiency, physiological efficiency.

INTRODUCTION

In terms of amount, nitrogen is the most important nutrient that plants obtain from the soil (Lonhienne *et al.*, 2008). It has long been understood that nitrogen molecules with low molecular masses, such as ammonium, nitrate, and amino acids, are taken up by plant roots. However, in natural ecosystems, the majority of the nitrogen is contained in the soil as proteins. The direct availability of this complicated organic form of nitrogen to plants is assumed to be negligible.

Although the majority of living things cannot use nitrogen in its natural state as dinitrogen (nitrogen gas, N2), it must be converted to a more usable form, such ammonia. Sutton, opined that Humans have historically made use of the ability of legumeous legumes to fix dinitrogen into usable reactive nitrogen molecules, increasing soil fertility. However, compared to what is already produced in the industrial sector, the amount of reactive nitrogen that is created in this way is insignificant. A web of unexpected effects is being produced by the nitrogen compounds that humans release into the atmosphere as well as nitrogen oxides, another reactive nitrogen byproduct produced during combustion processes (Sutton & Bleeker 2013). Until it is "fixed" biologically or abiotically (by lightning or aurorae, for example, or industrially), most organisms cannot use the majority of the nitrogen in the biosphere, which is in the form of N2 in the atmosphere. It typically either absorbs and becomes biological N or, after becoming fixed in NH_3, nitrifies into NO_3. The process of "ammonification" turns organic nitrogen back into NH_3 (Pal *et al.*, 2020). Through the processes of nitrification and denitrification, respectively, nitrate can be converted to N_2O and N_2. Ecosystems lose nitrogen as a result of this N_2O and N_2 generation, while the atmospheric nitrogen reserve acquires nitrogen (Stein & Klotz 2016).

The fourth most common element in living things, nitrogen, is used to create crucial biological substances including amino acids and nucleic acids Ohyama, (2010). Nitrogen is a structural constituent of nucleic acids, chlorophyll, proteins, Rubisco, and other substances. An essential agronomic management technique for raising crop productivity is N fertilisation. (Anas *et al.,* 2020). The functional activity of the photosynthetic machinery in leaves is significantly influenced by the availability of N in plants. Additionally, it has been noted that efficient N feeding can reduce the negative consequences of drought stress by preserving metabolic functions even at low tissue water potential. (Ullah *et al.,* 2019). Excess nitrogen promotes aggressive growth in many plants, resulting in lush, dark-green growth, but it also affects plant development and may change the biology of plants, resulting in a longer vegetative phase, delayed maturity, a longer plant life cycle, and improved succulence. (Nadeem *et al.,* 2018.).

Genetic and environmental factors impact the effectiveness of wheat crops in using nitrogen. Kraisig *et al.* (2021) evaluated the characteristics of biomass, productivity, and grain quality as determined by the effectiveness of nitrogen consumption by wheat genotypes. The outcome showed that productivity (yield and biomass), nitrogen consumption efficiency, and wheat quality all showed genetic variations. Wheat crop yield and biomass daily rate-1 are considerably impacted by an increase in N-fertilizer. (Kumar *et al.,* 2022). The results showed that one variety had significantly higher tiller numbers per plant, plant height, shoot dry weight at 50% flowering and at physiological maturity, biomass yield, and straw yield, while another variety had significantly higher shoot dry weight at 50% flowering and at physiological maturity, total N uptake, grain P uptake, and agronomic efficiency (Harfe, 2017).

After nitrogen, phosphorus is the second most frequently limiting element for plant growth. It makes up about 0.2 percent of a plant's dry weight. Since phosphorus is a necessary component of numerous vital substances, such as phospholipids, ATP, and nucleic acids, plants require a steady supply of this mineral to survive (Behera *et al.,* 2014).

Grain crop productivity is limited by phosphorus (P), which is predicted to be more common in the future. To boost P efficiency (P-use efficiency), phosphorus absorption efficiency (P-acquisition efficiency) and productivity per unit of phosphorus taken up can both be improved (Simpson *et al.,* 2011). This review focuses on improved P-use efficiency, which may be attained by plants that have lower P concentrations overall. It also discusses the best P distribution and redistribution within the plant, which enables the allocation of the most biomass to harvestable plant parts and promotes maximum growth. Plant P pools are likely to decrease dramatically (Noushahi *et al.,* 2019).

Phosphorus is mainly transported linearly from mines to far-off locations for crop production, processing, and consumption, where a significant portion may eventually become agronomically inactive due to over-application, unsuitable for recycling due to fixation, contamination, or dilution, and harmful as a surface water pollutant due to fixation, contamination, or dilution. This sort of P consumption cannot continue since the supply of fossil phosphate rocks is limited. The soils in food-producing regions won't have enough phosphate when high-quality phosphate rock supplies run out, necessitating phosphate supplementation to allow for the efficient use of resources other than phosphate, like other nutrients (Schroder, 2011). There is potential for the development of plants that can absorb various forms of soil phosphorus, such as organic phosphorus, and use internal phosphorus more effectively (Kafle *et al.,*2019). Yinghua Duan (2014) stated that An efficient nutrition management strategy is to make sure the wheat crop has an adequate amount of P. The study's findings demonstrated the importance of P in raising NUE by showing that both wheat types produced higher yields, NUE, and NAE in the NP and NPK treatments compared to N and NK treatments.

The study's findings suggest that utilizing too much nitrogen increases production costs and decreases economic advantages, and that the production of wheat can be boosted by choosing genotypes with greater NUE (Eshetu, 2022).According to Nasri (2014), nitrogen use efficiency (NUE), nitrogen uptake efficiency (NUpE), nitrogen utilization efficiency (NUtE), and nitrogen efficiency ratio (NER) in wheat were all significantly impacted by crop rotation, nitrogen fertilizer, as well as their interaction. The lowest and highest NUE, respectively, were found in the cycles of oilseed radish and fallow wheat. The rotations with the highest and lowest NUtE were oilseed radish-wheat and fallow-wheat, respectively. According to Daba1(2017), differences in NUpE rather than NUtE were primarily responsible for cultivar-to-cultivar variations in NUE and GY at low N application levels. The effectiveness of various combinations of N rates with application duration must therefore be studied in order to maximise N-use efficiency features and cost effectiveness.

MATERIALS AND METHODS

Field Experiments

Location and climate. The field study was carried out at the ICAR-IISS research farm in Bhopal, Madhya Pradesh, during the rabi season of 2020–21. It is classified as semi-arid and subtropical and has scorching summers and frigid winters. The Vindhyan Plateau Agro climatic Zone includes Bhopal. About 1100 mm of precipitation falls on average each year, with the majority falling from July to September during the monsoon season. Summertime highs are often 35 to 40 °C, while wintertime lows are typically 2 to 9 °C.

Experimental field. Nine varieties of wheat (*T. aestivum* and *T. durum*) crop were selected and grown as test crop in the current investigation adopting split plot design replicated thrice with nutrient dose as the main plot and varieties as sub plot treatment there are 36 plots in a block (9 variety × 4 fertilizer N and P treatments). The area of each plot is 2m × 2m. The initial soil parameters of the given experimental field are given in Table 1.

Land preparation. The experiment was set up in a split plot design with three replications. Each replication contained three nitrogen levels, three P levels, and nine genotypes for a total of 36 treatments. All of the treatments were divided up independently in each replication.

Table 1: Initial Physico chemical properties and nutrient availability of soil.

Sr. No.	Soil parameter	(0-15cm)	(15-30cm)	Methods
1.	pH (1:2.5 soil/water ratio)	7.88	7.88	Jackson, (1973)
2.	Electrical conductivity (dSm^{-1})	0.18	0.16	Jackson, (1973)
3.	Organic Carbon	0.65	0.52	Walkley and Black, (1934)
4.	Available Nitrogen	198	181	Subbiah and Asija (1956)
5.	Available Phosphorus	8.07	8.01	Olsen *et al.*, (1954)
6.	Available Potassium	475	351	Hanway and Heidel, (1952)

T_1=Control, T_2=100% (N+P+K) T_3= 50% N+ 100% (P+K), T_4 =50%P+100%N+K
V_1 to V_9 =HI8663, HI8737, HI8713, HI1563, HI1544, HI1531, GW366, LOK1, NARMADA14

Table 2: Fertilizer nutrient levels (N&P dose): 4.

Symbol	Treatment	Description
T1	Control	No fertilizers added
T2	100% (N+P+K)	120 kg/ha N + 60 kg/ha P_2O_5 + 40 kg/ha K_2O
T3	50%N +100% (P+K)	60kg/ha N + 60 kg/ha P_2O_5 + 40 kg/ha K_2O
T4	100%(N+K) +50% P	120 kg/ha N + 30 kg/ha P_2O_5 + 40 kg/ha K_2O

Note: RDF @120:60:40 kg/ha of N, P_2O_5 and K_2O were supplied through Urea, SSP and MOP, respectively. 50% of N, 100% of P_2O_5 and 100% of K_2O of the respective treatments were applied as basal and rest 50% of the N dose was applied in two top dressings at 22 DAS and 45 DAS.

Main Plot Treatment details

Sub Plot Treatment details

Nine varieties of wheat. V_1 to V_9= HI8663, HI8737, HI8713, HI1563, HI1544, HI1531, GW366, LOK1, NARMADA14

Seed rate and sowing. The wheat genotypes were manually planted in lined furrows at a rate of 100 kg/ha on November 25, 2020, about 3 cm deep, with a row-to-row distance of 22.5 cm and a plant to plant distance of 5 cm. Before planting, chemical fertilizers (SSP) were placed underneath the seed in furrows. After sowing, the seeds were covered with soil and the furrows were carefully levelled.

Plant biomass and grain yield. The crop was harvested after it reached maturity, when the foliage had faded and the ears had assumed a yellowish hue. To eliminate the border impact, one border row from both sides and 30 cm from either end of each plot were collected. The remaining experimental plots were harvested with sickles, with ears detached and plant biomass wrapped into bundles. Each treatment's plant biomass (kg/ha), grain yield (kg/ha), and straw yield (kg/ha) were measured individually and weighed.

Collection and Preparation of Soil Samples

Soil samples were collected from experimental fields at 0-15 cm depth before sowing and after harvesting of the crop with the help of soil auger. Each soil sample was air-dried and sieved through 2 mm sieve. The processed soil samples were used for the laboratory analysis for the measurement of different of the soil parameters.

Soil Analysis. All soil samples were analyzed for the following physic-chemical properties of the soil using standard analytical method.

Soil pH. Using a pH meter with a glass electrode and 1:2.5 soil water suspensions, the pH of the soil was determined (Jackson, 1973).

Electrical conductivity (dSm^{-1}). The supernatant liquid from the soil suspension, which had previously been used to determine pH, was utilized to determine electrical conductivity using a conductivity meter (model-105 Aplus) (Jackson, 1973).

Organic carbon. The Walkley-Black (2013) dichromate wet oxidation method was used to calculate organic carbon (1934). Using the heat of dilution of H_2SO_4, organic materials in the soil was oxidised with a mixture of potassium dichromate ($K_2Cr_2O_7$) and concentrated H_2SO_4. $K_2Cr_2O_7$ that was not used was re-titrated using ferrous ammonium sulphate.

$$\mathbf{SOC\ \% = \frac{10(B - S)\ X\ 0.003\ X\ 100}{B\ X\ W}}$$

Where, B= blank reading; S= sample reading; W= weight of the soil sample

Available Nitrogen. The alkaline $KMnO_4$ method, in which the organic matter in the soil was oxidized with a hot alkaline $KMnO_4$ solution, was used to estimate available nitrogen. The ammonia (NH_3) that was produced during the oxidation process was distilled and trapped in boric acid and a mixed indicator solution. By titrating with standard acid, the amount of NH_3 trapped was calculated (Subbaiah and Asija 1956).

$$N\,(kg\,ha^{-1}) = \frac{(S - B)\ X\ Normality\ of\ H_2SO_4 X\ 14\ X\ 2.24\ X\ 10^6}{1000\ X\ W}$$

Where, B= blank, S=sample

S= Sample reading; W= weight of the soil sample

Nutrient analysis of plant samples. Plant samples (grain and straw) were collected and dried in a 70°C oven, after which the dried materials were ground to a

0.5 mm size in an electric grinder. The examination of N, P, and K was performed on these samples.

Determination of Nitrogen. KEL PLUS nitrogen assessment estimates nitrogen as the most important nutrient for live plants. The Kjeldahl (1883) method was used to estimate nitrogen using the Pelicans KEL PLUS System. The following three procedures were primarily used to estimate nitrogen determination. Digestion, distillation, and titration are the three steps in the process.

Digestion Process. A 0.5 g oven dried ground plant sample was transferred to the digestion tube throughout this procedure. To the sample, 10 mL concentrated sulphuric acid and 2 g digestion activator (K_2SO_4 + $CuSO_4$ in a 20:1 ratio) were added. The digestion block was heated after the digestion tubes were put into the digester. The sample turned colorless or light green at the end of the digestive process.

Distillation process

After neutralizing the acid in the digested sample with 40 percent alkali (NaOH) on heating, the ammonium radicals were transformed to ammonia during distillation under excess alkali conditions. The digested samples are heated by passing steam in the distillation unit (DISTYL-EM), and the ammonia freed by adding 40 percent NaOH is dissolved in 4 percent boric acid. Titration was performed on the ammonia in boric acid.

Titration Process. The standardized H_2SO_4 was used to titrate the boric acid and mixed indicator solution containing the "distilled off" ammonia. It was also established the titration value of a blank boric acid and mixed indicator solution.

$$\textbf{Nitrogen\%} = \frac{(\textbf{Sample titer} - \textbf{Blank titer}) \times \textbf{Normality of } \mathbf{H_2SO_4} \times \mathbf{14} \times \mathbf{100}}{\textbf{Sample weight (g)} \times \mathbf{100}}$$

Nutrient use efficiency traits

Nutrient uptake

$$\textbf{Nutrient uptake (kg ha}^{-1}\textbf{)} = \frac{\textbf{Nutrient content (\%)X Yield (kg ha}^{-1}\textbf{)}}{\mathbf{100}}$$

Nitrogen use efficiency (NUE). NUE (agronomical and physiological) and nutrient recovery (ARN) by plant were computed as per the following formula.

$$\textbf{Agronomic use efficiency} = \frac{\textbf{Grain yield}_f\textbf{(kg ha}^{-1}\textbf{)} - \textbf{Grain yield}_c\textbf{(kg ha}^{-1}\textbf{)}}{\textbf{Fertilizer N applied (kg ha}^{-1}\textbf{)}}$$

$$\textbf{Apparent efficiency (\%)} = \frac{\textbf{Nutrient uptake}_f\textbf{ (kg ha}^{-1}\textbf{)} - \textbf{Nutrient uptake}_c\textbf{(kg ha}^{-1}\textbf{)}}{\textbf{Fertilizer N applied (kg ha}^{-1}\textbf{)}}\textbf{X100}$$

$$\textbf{Physiological use efficiency (\%)} = \frac{\textbf{Grain yield}_f\textbf{ (kg ha}^{-1}\textbf{)} - \textbf{Grain yield}_c\textbf{(kg ha}^{-1}\textbf{)}}{\textbf{Nutrient uptake}_f\textbf{ (kg ha}^{-1}\textbf{)} - \textbf{Nutrient uptake}_c\textbf{(kg ha}^{-1}\textbf{)}}$$

Where, f= fertilized crop; c = unfertilized (control)

RESULT AND DISCUSSION

A. Plant biomass and Grain yield

Among all the treatments, the highest Plant biomass was observed in NARMADA 14 both under normal dose of fertilizer treatment (10377.25 kg/ha) and reduced P dose fertilizer treatment (9670.25 kg/ha). Lower Plant biomass was observed in HI 8663 (5101.50 kg/ha) in control plot (Table 3 4.1). Among all the treatments, the highest grain yield was observed in HI 8713 (4580.88 kg/ha) and it was followed by HI 1531 (4405.13 kg) in normal fertilizer dose. Lowest grain yield was observed in HI 1563 (2084.88 kg) in control plot. Total biomass yield is the total dry matter generated by a plant as a result of photosynthesis and nutrient uptake after accounting the losses during respiration (Shah,1994). The selected nine wheat cultivars have shown considerable variations in biological yield (t/ha). There was a lot of interaction between nine cultivars and the four levels of nutrients (Nitrogen and Phosphorus treatments). As the amount of nitrogen and phosphorus application was increased from the control level to 60 kg/ha and 120 kg/ha, the biological yield increased. Normal dose treatment yielded the highest biological output (10.37 t/ha). NARAMADA 14 had the highest biological yield, followed by HI 1563 (9.6 t/ha) and HI 1544 (9.5 t/ha). The high yield of NARAMADA 14 might be attributable to the increased leaf area and dry weight characteristics (Table 3). The biological yield of HI8663 was the lowest (5.1 t/ha). In the present study, nitrogen and phosphorus levels, as well as the cultivars, had a substantial interaction. These findings were consistent with those of Iqbal *et al.* (2014), who found that raising nitrogen levels boosted biological yield. These findings corroborated those of Shafi *et al.* (2020), who found that plots treated with full dose of nitrogen per hectare yielded the highest biomass. In the current study, greater nitrogen and phosphorus administration resulted in higher plant dry weight. Sharma *et al.* (2017) also reported substantial differences in plant dry weight in wheat grown with graded nitrogen fertilizer doses. This was consistent with the current study's findings, which revealed that enhanced nitrogen fertilization resulted in higher dry weight.

Optimum and recommended quantities of nitrogen and phosphorus boosted wheat grain yield considerably. Normal dose treatment produced the highest grain yield (4580.88 kg/ ha), while control plot produced the lowest grain yield (1715.63 kg/ ha) due to the lack of nitrogen and phosphorus application. Among all of the basic nutrients provided to plants, nitrogen and phosphorus are the most important, as they play a crucial role in photosynthesis. As sufficient nitrogen and phosphorus were applied, the rate of photosynthesis increased, resulting in a higher assimilation and transport of dry matter to fill the seeds thereby enhancing grain yield. The findings are consistent with those of Hati *et al.,* (2015), who found a considerable increase in wheat grain production with increased nitrogen fertilizer treatment. There has been differential increase in wheat yield using nitrogen fertilizer on several occasions Zhang *et al.,* 2012). Bulut *et al.,* 2022) reported that higher nitrogen dosages had a significant impact on grain yield. Increasing the N rate resulted in an increase in biomass at later stages of growth, but had no effect at the start. The effect of nitrogen and phosphorus on seed yield could be due to nitrogen's influence on photosynthesis, the amount of photo-assimilates produced by the plant, dry matter partitioning, and organ development. The influence of nitrogen on photosynthesis could have an impact on the yield components (Omran *et al.,* 2016).

Table 3: Effect of N & P on grain yield and total biomass yield of wheat genotypes.

	Plant Biomass(kg/ha)					Grain Yield (kg/ha)				
	T_1	T_2	T_3	T_4	Mean A	T_1	T_2	T_3	T_4	Mean A
HI8663	5,101.50	8,083.00	5,858.25	6,340.50	6,345.81	2,314.75	3,961.88	2,816.13	3,457.13	3,137.47
HI8737	7,191.25	8,050.25	7,687.25	8,088.50	7,754.31	2,373.88	4,022.25	3,070.88	3,575.25	3,260.56
HI8713	8,383.00	9,393.00	7,913.25	7,948.25	8,409.38	3,035.13	4,580.88	3,996.63	4,190.88	3,950.88
HI1563,	7,245.75	8,315.75	7,905.63	9,657.75	8,281.22	2,084.00	4,308.75	4,123.38	2,719.75	3,308.97
HI1544	7,147.50	8,374.75	7,518.50	9,563.75	8,151.13	2,093.00	4,225.50	3,019.13	2,810.25	3,036.97
HI1531	7,100.00	8,968.75	7,755.20	8,025.00	7,962.24	2,576.13	4,405.13	3,675.00	4,010.88	3,666.78
GW366	7,667.75	9,456.50	8,751.25	8,547.50	8,605.75	2,095.00	4,272.38	4,110.13	2,914.38	3,347.97
LOK1	8,201.75	9,105.63	8,781.25	8,864.50	8,738.28	1,715.63	3,426.50	3,404.63	3,195.00	2,935.44
NARMADA14	7,923.75	10,377.25	8,465.25	9,670.25	9,109.13	1,888.25	4,293.63	4,164.00	3,721.88	3,516.94
Mean B	7,329.14	8,902.76	7,848.43	8,522.89		2,241.75	4,166.32	3,597.76	3,399.49	
Factors	**C.D.**	**SE(d)**			**SE(m)**	**C.D.**	**SE(d)**			**SE(m)**
Factor (A)	182.07	55.24			39.06	62.89	19.08			13.49
Factor (B)	163.38	79.85			56.46	76.51	37.39			26.44
Factor (B) at same level of A	350.44	159.69			117.18	159.40	74.79			40.47
Factor (A) at same level of B	351.94	160.37			113.40	155.69	73.04			51.65

T_1= Control, T_2=100% (N+P+K) T_3= 50% N+ 100% (P+K), T_4 =50%P+100%N+K

B. Nitrogen/ nutrient use efficiency (NUE) traits

Nitrogen content (%). Among all the treatments, the highest N% in grain was observed in HI 1544(1.82 %) followed by HI 8737(1.80 %) in normal Dose fertilizer treatment and lower N% in grain was observed in LOK1 (1.29 %) in reduced phosphorus dose fertilizer (Table 4). There were significant differences in N% in straw observed between varieties of wheat and fertilizer treatments. The range of N% in straw was found in between 0.12 (HI8663) to 0.42% (NARMADA14) among all the treatments (Table 4).

Among the varieties grown in half dose of N fertilizer treatment the highest N% in straw was observed in HI1544 and HI8737 (0.36%) followed by LOK1 (0.34%) and among the varieties grown in half dose of P, the highest N% in straw was found in HI1563 and GW366 (0.33%) followed by HI8663(0.31%). Among all the treatments, the highest N% in straw was observed in NARMADA 14(0.42%) followed by HI1544 (0.41) %) in normal Dose fertilizer treatment and lower N% in straw was observed in HI8663 (0.12 %) in control (Table 4.2).

In the present study, increase in nitrogen content of grain and straw was observed with increase in N fertilization. This was corroborated by the works of (Rafiq *et al.* 2023) wherein higher N content was reported with increase in N dose. This may be due to higher uptake of N by plants owing to higher availability

Nitrogen uptake. There were significant differences in N uptake in grain among the varieties of wheat and fertilizer treatments. The range of N uptake in grain was found in between 19.85 (LOK1) to 67.05 kg/ha (HI8713) among all the treatments (Table 5). The mean N uptake in grain was higher in normal dose treatment followed by reduced nitrogen dose fertilizer treatment, reduced phosphatic fertilizer dose treatment and lower in control plots.

There were significant differences in N uptake in straw observed between varieties of wheat and fertilizer treatments. The range of N uptake in straw was found in between 5.10 (HI8663) to 35.88 kg/ha (Narmada14) among all the treatments (Table 5). The mean N uptake in straw was higher in Normal dose treatment followed by reduced nitrogen dose fertilizer treatment, reduced phosphatic fertilizer dose treatment and lower in control plots. Among the varieties grown in full dose of N & P treatment, the highest N uptake in straw was found in Narmada14 (35.88kg/ha) and the lowest was found in HI8663 (24.79kg/ha). Among all the treatments, the highest N uptake in straw was observed in Narmada 14 (35.88 kg/ha) followed by HI8713 (30.84 kg/ha) in normal dose fertilizer treatment and lower N uptake in straw was observed in HI8663 (5.10 kg/ha) in control plot (Table 5).

There were significant differences in total N uptake observed between varieties of wheat and fertilizer treatments. Among the varieties grown in full dose of N & P treatment, the highest total N uptake was found in HI8713(97.89 kg/ha) and the lowest total N uptake was found in LOK1 (73.50 kg/ha). Among all the treatments, the highest total N uptake was observed in HI8713 (97.89 kg/ha) followed by NARMADA14 (92.29 kg/ha) in normal Dose fertilizer treatment and lowest total N uptake was observed in LOK1 (30.85 kg/ha) in control plots (Table 5).

Across all treatments, total N uptake followed the trend of HI8713 > HI1563 > HI1531 > HI8737> NARMADA 14> HI1544 >GW366> HI8663 > LOK1.

According to Afridi *et al.*, (2014) grain and straw nitrogen uptake increased as nitrogen fertilizer levels increased. This was in conformity with the current results from this study which revealed that increasing the fertilizer dose resulted in higher nitrogen uptake. There was a lot of variation in total nitrogen uptake across the genotypes used in the current investigation. Similar genetic variation in wheat was reported by Tian *et al.* (2016) for nutrient uptake efficiency. The analysis demonstrated that varied quantities of nitrogen application had a considerable impact on nitrogen uptake (Table 5).

Table 4: Effect of N & P on nitrogen content in grain and straw of wheat genotypes.

	Nitrogen in Grain (%)					Nitrogen in Straw (%)				
	T_1	T_2	T_3	T_4	Mean A	T_1	T_2	T_3	T_4	Mean A
HI8663	1.52	1.78	1.77	1.73	1.70	0.12	0.37	0.27	0.31	0.27
HI8737	1.75	1.80	1.63	1.46	1.66	0.22	0.40	0.36	0.25	0.31
HI8713	1.52	1.76	1.59	1.56	1.61	0.20	0.39	0.28	0.19	0.27
HI1563	1.66	1.72	1.66	1.46	1.62	0.19	0.37	0.33	0.33	0.30
HI1544	1.77	1.82	1.68	1.72	1.75	0.21	0.41	0.36	0.23	0.30
HI1531	1.46	1.58	1.61	1.45	1.52	0.18	0.39	0.30	0.23	0.28
GW366	1.44	1.66	1.36	1.48	1.48	0.17	0.37	0.31	0.33	0.30
LOK1	1.39	1.57	1.29	1.34	1.40	0.16	0.38	0.34	0.23	0.28
NARMADA14	1.38	1.58	1.39	1.41	1.44	0.26	0.42	0.26	0.22	0.29
Mean B	1.54	1.69	1.55	1.51		0.19	0.39	0.31	0.26	
Factors	C.D.	SE(d)		SE(m)		C.D.	SE(d)			SE(m)
Factor(A)	0.092	0.028		0.02		0.02	0.01			0
Factor(B)	0.053	0.026		0.018		0.02	0.01			0.01
Factor(B)at same level of A	0.122	0.052		0.06		0.05	0.02			0.01
Factor(A)at same level of B	0.133	0.056		0.04		0.04	0.02			0.01

T_1=Control, T_2=100% (N+P+K) T_3= 50% N+ 100% (P+K), T_4 =50%P+100%N+K

Table 5: Effect of N & P on nitrogen uptake in grain and straw and total uptake of wheat genotypes.

	N Uptake in grain (kg/ha.)					N Uptake in straw(kg/ha.)					Total N uptake (kg/ha.)				
	T_1	T_2	T_3	T_4	Mean A	T_1	T_2	T_3	T_4	Mean A	T_1	T_2	T_3	T_4	Mean A
HI8663	29.32	58.93	41.36	49.62	44.80	5.1	24.79	13.17	16.11	14.79	34.42	83.72	54.53	65.72	59.59
HI8737	34.53	60.22	41.75	43.41	44.98	13.33	26.97	22.74	16.88	19.98	47.86	87.19	64.50	60.30	64.96
HI8713	38.39	67.05	52.94	54.52	53.22	14.22	30.84	18.47	12.59	19.03	52.61	97.89	71.41	67.11	72.25
HI1563,	28.80	61.64	56.88	33.02	45.08	11.23	25.94	21.54	26.24	21.24	40.03	87.58	78.42	59.26	66.32
HI1544	30.83	64.02	42.13	40.25	44.31	12.66	28.26	22.4	18.25	20.39	43.49	92.28	64.52	58.50	64.70
HI1531	31.27	57.77	49.30	48.27	46.65	10.56	29.45	19.52	15.52	18.76	41.83	87.22	68.81	63.78	65.41
GW366	25.11	59.05	46.58	35.85	41.65	11.12	29.08	22.54	23.44	21.54	36.23	88.12	69.11	59.29	63.19
LOK1	19.85	44.78	36.40	35.72	34.19	11.01	28.72	24.66	17.07	20.36	30.85	73.50	61.06	52.79	54.55
NARMADA14	21.73	56.41	48.27	43.57	42.49	17.23	35.88	18.31	17.49	22.23	38.97	92.29	66.57	61.05	64.72
Mean B	28.87	58.87	46.18	42.69		11.83	28.88	20.37	18.18		40.70	87.75	66.55	60.86	
Factors	C.D.	SE(d)			SE(m)	C.D.	SE(d)			SE(m)	C.D.	SE(d)			SE(m)
Factor(A)	3.838	1.164			0.823	1.09	0.33			0.24	4.5	1.365			0.965
Factor(B)	1.865	0.912			0.645	1.41	0.69			0.49	2.617	1.279			0.904
Factor(B)at same level of A	4.447	1.823			2.47	2.93	1.38			0.7	6.01	2.558			2.896
Factor(A)at same level of B	5.065	2.076			1.468	2.85	1.34			0.95	6.511	2.771			1.96

Maximum uptake of 28.88 kg/ha was observed in straw when N was applied at 120 kg/ha, while the smallest value of 11.83 kg/ha was obtained at 0 kg/ ha. The application of N at a rate of 120 kg/ha resulted in an increase in N absorption. Increased N uptake by the wheat crop was also a result of the application of P. Applying 120 N kg/ha and P 60 kg/ha resulted in a maximum N absorption of 87.75 kg/ha, which was 54.6% greater than the control plots. These findings are comparable to those of Belete *et al*., (2018) who found that nitrogenous fertilizer increased total N uptake. They reported that nitrogen uptake is improved by the application of nitrogenous and phosphorous fertilizers which are in agreement with the findings.

Nitrogen use efficiencies. There was a significant difference in Agronomic Use Efficiency (AUE) based on N application observed between varieties of wheat and fertilizer treatments. Among the varieties grown in full dose of N & P treatment, the highest AUE was found in HI1563 (13.74%) and the lowest AUE was found in HI 8737 (4.18%). Under half dose of N fertilizer treatment, the highest AUE was observed in HI8663 (18.54%) followed by HI1563 (17.77%) and in half dose of P, the highest AUE was found in GW366 (20.05%) followed by LOK1 (18.97 %). Among all the treatments, the highest AUE was observed in GW366 (20.05%) followed by lok1 (18.97%) in reduced P dose treatment and lower AUE was observed in HI8737 (4.18%) in normal dose treatment (Fig. 6).

There were also significant differences in ANR observed among varieties of wheat and fertilizer treatments. The range of ANR was found in between 15.90 (Narmada 14) to 95.96% (HI1563) among all the treatments. The mean ANR was higher in reduced nitrogen dose fertilizer treatment followed by reduced phosphatic fertilizer dose treatment and Normal dose treatment Table 6. Among all the treatments, the highest ANR was observed in HI1563 (95.96%) followed by GW366 (88.13%) in reduced N dose treatment and lower ANR was observed in Narmada 14 (15.90%) in normal dose treatment.

There were also significant differences in PUE observed between varieties of wheat and fertilizer treatments. The range of PUE was found in between 12.26 (HI8713) to 70.31 % (LOK1) among all the treatments (Table 6). Among all the treatments, the highest PUE was observed in LOK1 (70.31%) in reduced P dose treatment and it was followed by Narmada 14 (66.75%) in same treatment and lower PUE was observed in HI8713 (12.26 %) in reduced N dose treatment (Table 6).

In the present investigation, decrease in nitrogen use efficiency was observed with increase in N dose. The lower levels of N dose resulted in higher use efficiency. These results were in conformity with several reports. Nitrogen fertilizers applied to winter wheat recovered 50-60% of their nitrogen, according to Abbasi *et al*., (2012). This was consistent with current data, which showed that ANR levels in the selected wheat varieties ranged from 26 to 58 percent. Lower nitrogen treatment doses resulted in higher N use efficiency, according to Meena *et al.,* (2016); Kaur *et al.,* (2022), and later research have found that N use efficiency varied by type. Variability in efficiency was also observed in the current wheat genotype collection.

Table 6: Effect of N on nutrient use efficiencies of wheat genotypes.

	Agronomic use efficiency (%)				Apparent nitrogen recovery (%)				Physiological use efficiency (%)			
	T_2	**T_3**	**T_4**	**Mean A**	**T_2**	**T_3**	**T_4**	**Mean A**	**T_2**	**T_3**	**T_4**	**Mean A**
HI8663	13.73	18.54	18.15	16.80	41.07	87.62	45.93	58.21	33.41	21.06	39.51	31.32
HI8737	4.18	17.00	16.79	12.66	18.16	77.88	31.29	42.44	23.03	22.14	53.77	32.98
HI8713	9.52	5.30	6.83	7.22	23.00	44.23	22.23	29.82	43.25	12.26	30.73	28.74
HI1563,	13.74	17.77	14.26	15.26	37.78	95.96	38.80	57.51	36.35	18.23	36.76	30.44
HI1544	5.81	7.72	14.08	9.20	19.29	44.13	28.85	30.76	30.13	17.85	48.82	32.26
HI1531	10.01	5.98	12.33	9.44	16.94	37.99	21.93	25.62	59.13	16.17	56.30	43.86
GW366	12.88	15.24	20.05	16.06	43.56	88.13	46.99	59.56	29.57	17.51	42.68	29.92
LOK1	8.01	9.16	18.97	12.05	18.72	55.36	27.01	33.70	42.93	16.86	70.31	43.37
NARMADA14	9.63	11.96	15.28	12.29	15.90	44.24	22.91	27.68	60.63	27.64	66.75	51.67
Mean B	9.72	12.07	15.19		26.04	63.95	31.77		39.82	18.85	49.51	
Factors	**C.D.**	**SE(d)**		**SE(m)**	**C.D.**	**SE(d)**		**SE(m)**	**C.D.**	**SE(m)**		**SE(m)**
Factor(A)	0.92	0.20		0.14	2.98	0.64		0.46	6.46	1.40		0.99
Factor(B)	0.89	0.43		0.30	1.97	0.95		0.67	4.05	1.95		1.38
Factor(B)at same level of A	1.69	0.75		0.42	4.02	1.64		1.37	8.40	3.38		2.96
Factor(A)at same level of B	1.65	0.73		0.52	4.11	1.67		1.18	8.65	3.48		2.46

T_1=Control, T_2=100% (N+P+K) T_3= 50% N+ 100% (P+K), T_4 =50%P+100%N+K

SUMMARY & CONCLUSION

1. The variety HI8713 produced noticeably more plant biomass under normal, and control fertiliser dose conditions, achieving 9393.00 kg/ha and 8383.00 kg/ha. Under identical fertiliser doses, the same variety produced noticeably higher grain yields of 4,580.88 kg/ha. and 3,035.13kg/ha. respectively.
2. Under low dose of N, the variety HI 1563 had the highest apparent recovery of N (95.96 %), followed by GW366 (88.13%). Across all fertilizer N dosages, the highest average Agronomic Efficiency was found in GW366 (20.05%). Under normal N conditions, variety Narmada14 had the highest Physiological Efficiency (60.63 percent), followed by HI1531, *i.e.* 59.13 percent.
3. Among all the wheat varieties tested, the variety HI 8713 had considerably higher dry weight, leaf area, biomass, grain yield, chlorophyll content, SPAD value, nitrogen content in grain and straw, total nitrogen uptake, agronomic use efficiency by N, nitrogen harvesting index, photosynthetic rate, total phosphorus uptake, apparent phosphorus recovery and phosphorus harvesting index and lower days to 50% flowering.
4. Between sub optimal doses of N and P (T_3 and T_4) T_3 produced higher biomass yield than T_4 averaging all the selected nine varieties of wheat, whereas T_4 had higher grain yield than T_3.
5. Use efficiency terms namely agronomic use efficiency, apparent nutrient recovery and physiological efficiency calculate based on N application and P application were highly variable depending on rates of N & P application and genotypes and were not without bias. In general, agronomic use efficiency and physiological use efficiency calculate on P basis were much higher than those calculated on N basis.

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