Original Research Article

"Effect of Nitrogen and Phosphate fertilizer on Phosphorus uptake andPhosphorus use efficiency in some of wheat varieties"(*T.aestivum* and *T. durum*)

ABSTRACT

A field experiment was carried out in a subtropical region of India. The main purpose of this experiment was to grow different wheat genotypes under different nutrient doses and find out which genotype performed better in terms of yields and other attributes under nutrient constraints. Nine varieties of wheat (*T. aestivum* and *T. durum L.*) were selected and grown as test crops in the current investigation, adopting a split plot design that was replicated three times, with nutrient dose as the main plot and varieties as sub treatments. In the treatmentT_1 = control, T_2 = 100% (N+P+K), T_3 = 50% N+100% (P+K), and T_4 = 50% P+100% N+K, there are 36 plots in a block (9 varieties x 4 fertilizer N and P treatments). Of the nine varieties grown under normal N and P conditions, varieties NARMADA 14 and GW 366 had the highest P content in grain and straw. GW366 (10.93 kg/ha) had the highest average total P uptake, followed by NARMADA14 (10.90 kg/ha). Under normal doses of N and P, the variety HI 1531 (15.25%) had the highest apparent recovery of P, followed by NARMADA14 (15.15percent).Across all fertilizer N and P dosages, the highest average agronomic efficiency for P was found in GW366 (40.09%), followed by LOK1 (37.93%). NARMADA 14 and GW366 have the highest P content in grain and straw of the nine varieties grown under normal nitrogen conditions. Agronomic use efficiency and physiological use efficiency were generally substantially higher when computed on a P basis than they were when calculated on an N basis.P fraction concentrations in black soil varied, but they responded similarly to crop species and N sources. The N supply had an impact on the amounts of P taken from the soil. In P-deficient soils, the use of an appropriate N source and the selection of the right crop species may boost crop yield and plant P uptake.

Key words Nucleic acids, Genotypes, Varieties, Efficiency, Nutrient

1. INTRODUCTION

Every Plant cannot survive without a consistent supply of nutrients. Fertilizer management strategies that supply nutrients at the proper rate, timing, and site can improve fertilizer use efficiency.

Phosphorus is an important compound that includes nucleic acids, phospholipids, and ATP(adenosine triphosphate). Plants cannot thrive without a consistent supply of these nutrient Fertilizer management strategies that apply nutrients at the proper rate, timing, and site can improve fertilizer use efficiency. P is very stable or insoluble in all of its natural forms, including organic forms, and only a small amount of it exists in the soil solution at any given moment. Because it is the amount of phosphorus that will enter the soil solution and be taken up by the crop during its life cycle, the quantity of accessible P is time and crop-specific. The concentration of accessible P (availability) in the soil solution is the easiest way to determine its intensity. The global PUE for cereal production was predicted to be 16 percent [3].

Phosphorus (P) limits grain crop productivity and is expected to become more prevalent in the future. Phosphate absorption efficiency (P-acquisition efficiency) and productivity per unit P taken up can both be improved to increase P efficiency (P-use efficiency). This review focuses on increased P-use efficiency, which can be achieved by plants with lower P concentrations overall, as well as by optimal P distribution and redistribution in the plant, which allows for maximal growth and biomass allocation to harvestable plant sections. It's probable that plant P pools will drop significantly [19].

Phosphorus (P), like nitrogen (N), is an important nutrient for plant growth and productivity. Its content in plants ranges from 0.05 to 0.5 percent of the total dry weight of the plant. Despite the fact that the concentration of P in soil is 2000 times higher than in plants, its fixation in the form of aluminium/iron or calcium/magnesium phosphates prevents plants from absorbing it [17]. Phosphorus is involved in a variety of biological functions, including membrane structure maintenance, biomolecule synthesis, and the production of high-energy molecules. Cell division, enzyme activation/inactivation, and glucose metabolism are all aided by it [17].

The declining availability of rock phosphate as a source of P fertilizer, combined with growing awareness of the negative environmental repercussions of high P fertilizer input, has piqued interest in improving plant P acquisition and usage efficiency [6].

Phosphorus (P) is an unsubstitutable, essential element for plant growth and is a structural component of major biomolecules such as nucleic acids, sugar phosphates, adenosine triphosphates, and phospholipids. Phosphorus (P) is one of the most important nutrients for plant growth and survival. It is essential for cellular bioenergetics and metabolic pathways within the plant body. The primary function of mineral fertilizers is to increase crop yields, but the biggest impediment to realizing known crop potential is the low use of fertilizers, notably P and N [4].

Seed P reserves are rapidly mobilised and translocated to emerging root and shoot tissues after germination, as it is the sole P source available to sustain seedling growth. This P supply is then replenished by P uptake by the root system as it develops [19].

Plants that can acquire different types of soil phosphorus (e.g., organic phosphorus) and utilise Internal phosphorus has the potential to be developed more efficiently [2].Wheat genotypes' varying genetic potential may account for their differential response to all of the investigated parameters under control (P 0.001) and treatment. To create phosphorus-efficient wheat cultivars, these genetic variations in wheat genotypes for P efficiency can be taken advantage of on phosphorus deficient soil.10].

Rasul[11]observed that varied phosphorus fertilizer rates (0, 150, 200, and 250 kg P_2O_5 $ha^{-1)}$ significantly affected chlorophyll content in the leaf, as well as protein content (percent), grain N (percent), and P (percent). The result also revealed that the 250 kg P_2O_5 ha^{-1} application had the highest P uptake by wheat grain (11.70 kg/ha), while the control had the lowest (3.30 kg/ha). Phosphorus utilization efficiency (PUE) was found to be decreased at greater P application rates. The phosphorus had an effect on the grain P physiological efficiency index (PEI) and it was found to have the lowest value (0.46 kg g^{-1}) in T_4 treatment(250 kg P_2O_5 ha^{-1}) and the greatest value (1.55 kg g^{-1}) in control.

2. Material and methods

The black cotton soil in subtropical region in India in this soil clay percentage in soil was more.Each plot has a space of 2 m by 2 m. The experiment's split plot design employed three replications. A total of 36 treatments, consisting of three levels of nitrogen and three levels of phosphorus in nine various varieties, were allowed for each replication.Both *T. aestivum*and*T. durum* varieties were treated as a subplot, whereas nutrient dose was treated as the main narrative. Three replications of a split plot design were used to set up the experiment. Nine genotypes, three nitrogen levels, three P levels, and a total of 36 treatments were present in each replication. In each replication, each treatment was broken up separately.

With a distance of 22.5 cm between rows and 5 cm between plants, the wheat types were manually planted on November 25, 2020, at a rate of 100 kg/ha in lined furrows that were approximately 3 cm deep. Prior to sowing, chemical fertilizers (SSP) were buried beneath the seeds in furrows. After sowing, the soil was lightly flattened over the furrows before the seeds were sown.
Crop, soil type, and source of nitrogen all had an impact on the amount of total P that was present as inorganic P. N fixing had a greater impact on the organic P fraction in black soil than did urea treatment. The type of soil and the type of crop had no discernible impact on the concentration of moderately labile organic P (MLOP).

Table2.1 Initial Physico chemical properties and nutrient availability of soil

S.no	Soil parameter	(0-15cm)	(15-30cm)	Methods
1	p^H (1:2.5 soil/water ratio)	7.88	7.88	Jackson, (1973)

2	Electrical conductivity (dSm-1)	0.182	0.16	Jackson, (1973)
3	Organic Carbon(%)	0.65	0.52	Walkley and Black, (1934)
4	Available Nitrogen(kg/hac.)	198.78	181.23	Subbiah and Asija (1956)
5	Available Phosphorus(kg/hac.)	8.07	8.01	Olsen *et al*, (1954)
6	Available Potassium(kg/hac.)	475.73	351.1	Hanway and Heidel, (1952)

Full-recommended doses of P and K fertilizers at 60 kg P_2O_5 and 40 kg K_2O per hectare ere treated as basal in SSP and MOP, respectively, in all treatments other than control. The control plots did not contain N or P. (T_1). While T_3 received half of the recommended amount of N (60 kg/ha) and the full dose of P (60 kg/ha), normal dose treatment (T_2) received the permitted amounts of N (120 kg ha-1) and P (60 kg/ha). Fertilizers were applied in full doses of N and P to the T_4 treatment. The remaining N is top dressed in equal splits at 25 and 45 DAS, while 50% of the applied N is supplied as basal.

Table 2.2 Nine varieties of Wheat

S. No	Variety	Description
V1	HI8663	*T. durum*
V2	HI8737	*T. durum*
V3	HI8713	*T. durum*
V4	HI1563	*T. durum*
V5	HI1544	*T.aestivum*
V6	HI1531	*T. aestivum*
V7	GW366	*T. aestivum*
V8	LOK1	*T. aestivum*
V9	NARMADA 14	*T. aestivum*

2.1 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 and P was performed on these samples.

2.2Determination of phosphorus

The amount of digested material was brought up to 100 ml in a volumetric flask, filtered through Whatsman No. 42 filter paper, and the filtrate was used to calculate P. Approximately 1 g of oven-dried ground plant material was placed in a 100 ml conical flask and digested with 10 ml of a di-acid mixture of AR grade concentrated HNO_3 and $HClO_4$ in 9:4 ratios.

2.2.1 Estimation of phosphorus

A 25 ml volumetric flask was filled with a 5 ml aliquot of the colorless filtrate, 5 ml of the ammonium molybdate vanadate combination, and 25 ml after vigorously shaking the mixture. According to Jackson, it was held for 30 minutes to let the yellow color develop, and the color intensity was measured at 470 nm in a spectrometer (type CE 2031), after calibrating the device with a blank and setting it to zero (1973).

2.3 Nutrient use efficiency traits

2.3.1Nutrient uptake

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

2.3.2Phosphorus Use Efficiency parameters

PUE (agronomical and physiological) and nutrient recovery (ARN) by plant were calculated using the formulas below.

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

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

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

3. Results and discussion

3.1 Phosphorous content (%)

The right amount of soil phosphorus (P) is necessary for optimum crop development, but too much P in the soil raises the possibility of P losses and the eutrophication of nearby surface waterways (Yang et al., [24]). There werenon-significant(0.05%) differences observed in P% in grain of varieties grown under fertilizer treatments. The range of P% in grain was found in between 0.069 (HI1531) to 0.151% (HI8663) among all the treatments (Table1). The mean P% in grain was higher in Normal dose treatment followed by reduced phosphatic fertilizer dose treatment, reduced nitrogen dose fertilizer treatment and lower in control plots. Among the varieties grown in full dose of N & P treatment, the highest P% in grain was found in HI8663 (0.151%) and the lowest P% in grain was found in HI1563 (0.125%). Among the varieties grown in half dose of N fertilizer treatment, the highest P% in grain was observed in HI8713 (0.127%) followed by GW366 (0.126%) and among the varieties grown in half dose of P, the highest P% in grain was found in GW366 (0.133%) followed by HI8737 (0.128%). Among all the treatments, the highest P% in grain was observed in HI8663 (0.151%) followed by HI1531 (0.145%) in normal dose fertilizer treatment and lowest P% in grain was observed in HI1531 (0.069 %) in control plot. Across all nutrient treatments% ingrain of selected wheat varieties followed the following trends: **GW366> NARMADA 14= HI8713> HI8737=HI8663 > LOK1 > HI1544 > HI1563 >HI1531** (Table1).

There were significant differences(0.05) in P% in straw observed between varieties of wheat and fertilizer treatments. The range of P% in straw was found in between 0.009 (HI1563) to 0.037 % (HI8663) among all the treatments (Table1). The mean P% in straw was the highest in Normal dose treatment followed by reduced phosphatic fertilizer dose treatment, reduced nitrogen dose fertilizer treatment and lower in control plots. Among the varieties grown in full dose of N & P treatment, the highest P% in straw was found in HI8663 (0.037%) and the lowest P% in straw was found in HI1563 (0.024%). Among the varieties grown in half dose of N fertilizer treatment the highest P% in straw was observed in HI8663 (0.028%) followed by HI8713(0.027%) and among the varieties grown in half dose of P, the highest P% in straw was found in HI8663 and GW366 (0.027%) followed by NARMADA14 (0.025%). Among all the treatments, the highest P% in straw was observed in HI8663 (0.037 %) under normal Dose fertilizer treatment and lowest P% in straw was observed in HI1563and HI1531 (0.009 %) under control plot (Table1).

Grain yield and grain P content were found to have a favorable relationship among all the varieties except in HI8713. Plants that accumulated comparatively more P in their grain produced higher grain yield in P-stressed plots, which could mean that plants that accumulated substantially more P in their grain produced higher grain yield. Our findings indicated that the varieties HI8713 and NARMADA14, which have better grain yield and P uptake, could be used as P-efficient cultivars on black cotton soils with a medium P fertility. Low grain P concentrations are advantageous under low P conditions, but they may cause issues with seed germination and food nutrition. To maintain seed viability, a minimum quantity of P content in grain must be present. However, by boosting P translocation into grain, significant grain production can be achieved without lowering grain P concentration. This idea was supported by a positive connection between grain production and grain P uptake in P-stressed plants.

Table1 Effect of N & P on phosphorus content in grain and straw of wheat genotypes

	P in grain (%)					P In straw (%)				
	T_1	T_2	T_3	T_4	Mean A	T_1	T_2	T_3	T_4	Mean A
HI8663	0.092	0.151	0.117	0.114	0.119	0.018	0.037	0.028	0.027	0.027
HI8737	0.095	0.140	0.113	0.128	0.119	0.014	0.034	0.023	0.023	0.023
HI8713	0.095	0.138	0.127	0.121	0.120	0.010	0.027	0.027	0.018	0.021
HI1563	0.084	0.125	0.110	0.122	0.110	0.009	0.024	0.018	0.023	0.018
HI1544	0.089	0.131	0.112	0.114	0.111	0.014	0.028	0.021	0.021	0.021
HI1531	0.069	0.145	0.110	0.113	0.109	0.009	0.032	0.023	0.018	0.020
GW366	0.104	0.137	0.126	0.133	0.125	0.012	0.029	0.018	0.027	0.021
LOK1	0.096	0.133	0.120	0.121	0.117	0.016	0.032	0.023	0.023	0.023
NARMADA14	0.095	0.137	0.120	0.127	0.120	0.015	0.032	0.023	0.025	0.024
Mean B	0.091	0.137	0.117	0.121		0.013	0.030	0.023	0.023	
Factors	**C.D.**		**SE(d)**		**SE(m)**	**C.D.**		**SE(d)**		**SE(m)**
Factor(A)	0.013		0.004		0.003	0.005		0.002		0.001
Factor(B)	NS		0.005		0.004	0.004		0.002		0.001
Factor(B)at same level of A	NS		0.011		0.009	NS		0.004		0.003
Factor(A)at same level of B	NS		0.011		0.008	NS		0.004		0.003

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

Table 2 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

Furthermore, significant P accumulation in grain and low accumulation in straw, as well as a high P harvest index of high-yielding genotypes (*T. durum*HI8713 and HI1563) under low P conditions as compared to that of genotypes grown with adequate P supply (Table1), suggested that P was efficiently trans located into grain. Therefore, these two genotypes can be used in genetic studies for investigating shoot and root traits, contributing to translocation of P from different plant parts to grain sink under low P conditions. Indicators of biomass and/or yield were shown to have a positive and substantial connection (r > 0.5) with root characteristics, which is assumed to be related to roots' enhanced synthesis of cytokinins, which are essential for partitioning biomass. This suggests that as P is absorbed and used more effectively, grain yield will increase [15].

3.2 P uptake

There were significant differences in P uptake in grain observed between varieties of wheat and fertilizer treatments. The range of P uptake in grain was found in between 2.74 (LOK1) to 10.61 kg/ha (HI1531) among all the treatments (Table 3). The mean P 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. Among the varieties grown in full dose of N & P treatment, the highest P uptake in grain was found in HI1531 (10.61kg/ha) and the lowest P uptake in grain was found in LOK1(7.57kg/ha).Under half dose of N fertilizer treatment, the highest P uptake in grain was observed in Gw366 (8.59kg/ha) followed by HI8713(8.45 kg/ha) and under half dose of P, the highest P uptake in grain was found in HI8713 (8.44 kg/ha) followed by NARMADA14(7.88 kg/ha).Among all the treatments, the highest P uptake in grain was observed in HI1531(10.61 kg/ha) followed by HI8713(10.49 kg/ha) in normal Dose fertilizer treatment and lowest P uptake in grain was observed in lok1 (2.74 kg/ha) in control plot(Table 3).

In straw there were significant differences in P uptake in straw observed between varieties of wheat and fertilizer treatments. The range of P uptake in straw was found in between 1.07 (HI1531) to 5.43 kg/ha (NARMADA14) among all the treatments(Table 3). The mean P uptake in straw was the highest in Normal dose treatment followed by reduced phosphatic fertilizer dose treatment reduced nitrogen dose fertilizer treatment and lower in control plots. Among the varieties grown in full dose of N & P treatment, the highest P uptake in straw was found in NARMADA14 (5.43 kg/ha) and the lowest P uptake in straw was found in HI1563 (3.25%). Among the varieties grown in half dose of N fertilizer treatment, the highest P uptake in straw was observed in HI8713 (3.56kg/ha) followed by LOK1 (3.36 kg/ha) and among the varieties grown in half dose of P, the highest P uptake in straw was found in NARMADA14 (4.04 kg/ha) followed by GW366 (3.78 kg/ha). Among all the treatments, the highest P uptake in straw was observed in NARMADA14 (5.43 kg/ha) followed by HI8663 (4.92 kg/ha) in normal Dose fertilizer treatment and lowest P uptake in straw was observed in HI1531 (1.07 kg/ha) in control plot (Table 3).

There were significant differences in total P uptake (grain plus straw) observed among the varieties of wheat and fertilizer treatments. The range of total P uptake was found in between 4.00 (HI1563) to 15.32 kg/ha (HI1531) among all the treatments (Table 3). The mean total P uptake was higher in Normal dose treatment followed by reduced phosphatic fertilizer dose treatment, reduced nitrogen dose fertilizer treatment and lower in control plots. Among the varieties grown in full dose of N & P treatment, the highest total P uptake was found in HI1531 (15.32 kg/ha) and the lowest total P uptake was found in HI1563(12.19%). Among the varieties grown in half dose of N fertilizer treatment, the highest total P uptake was observed in HI8713(12.01 kg/ha) followed by NARMADA14 (11.48 kg/ha) and among the varieties grown in half dose of P, the highest total P was found in NARMADA 14 (11.91 kg/ha) followed by HI8713 (10.83 kg/ha). Among all the treatments, the highest total P uptake was observed in HI1531 (15.32 kg/ha) followed by NARMADA 14(15.24 kg/ha) in normal Dose fertilizer treatment and lowest total P uptake was observed in HI1563 (4.00 kg/ha) in control plot Across all nutrient treatment total P uptake in selected wheat varieties followed the following trends:

HI8713>NARMADA>GW366>HI1531>HI8737>HI8663>LOK1>HI1563>HI1544(Table 3)

The chemical makeup of wheat plants revealed that, with the exception of the phosphorus concentration (%) in wheat straw, all parameters were greatly enhanced by the addition of P. Similar to how phosphorus application levels increased, phosphorus uptake did as well. According to the study's findings, phosphorus from various sources and concentrations affects wheat's NP content and total P uptake by plants in a substantial way [1].

Impact on phosphorus uptake (Table 3).Among all the varieties in total P uptake the mean maximum value of 10.93 kg/ha (HI8713) was detected, whereas the minimum value of 8.80 kg/ha(HI1563). The greatest P uptake of 10.61 kg/ha was recorded at 60 kg/ha P_2O_5 application and 120 kg/ha N application. The P uptake in grain was 3.5 times higher (HI1531) in normal dose than the control treatment that didn't have either N or P_2O_5. It was discovered that the interaction between N and P was substantial. These findings are backed up by[14]who found that applying mineral fertilizers at the proper time considerably improved wheat uptake of nutrients like P.

Only when the producing capacity of genotypes is compared at adequate and stress P levels can this differential behavior be meaningful. The genotype chosen based on absolute grain yield in relation to P-related parameters like P uptake, PHI, PAUE, and PPUE, APR would provide useful information about transferable genetic characters for developing future high-yielding P efficient cultivars, and the following interpretation is based on the yield and P uptake parameters from our study. At an adequate level of P conditions, genotypes NARMADA14, HI1531, HI8713 from the high-P-uptake group and LOK1, HI8737 from the medium-P-uptake group closely matched grain yield, but at Pstress conditions, they did not match it.Simulations show that P binds to a number of cations, reducing the amount of free phosphate ions in solution. The development of insoluble calcium phosphate species was caused by high pH levels [21].According to the traditional theory, maximal P solubility occurs at pH values of 4.5 and 6.5, respectively, and coincides with the levels of P fixing by Ca, Al, and Fe minerals that are the lowest [22]. Growth and P uptake were best in the neutral soils, lower in the acidic, and poorest in the alkaline soils[23].The fundamental issue with P application is the low efficiency of plant P uptake. In addition, nitrogen is essential for maintaining a consistently high output of wheat. The most significant nutritional interaction of practical importance might be said to be the interaction of N and P(Takahashi and Anwar [25]).

Table 3 Effect of N & P on phosphorus uptake in grain and straw of wheat genotypes

	P uptake by grain(kg/ha)					P uptake by straw(kg/ha)					Total P 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	3.55	9.90	5.49	6.58	6.38	1.53	4.92	2.73	2.85	3.01	5.08	14.82	8.22	9.43	9.39
HI8737	3.74	9.38	5.76	7.60	6.62	1.62	4.49	2.94	3.02	3.02	5.36	13.87	8.70	10.62	9.64
HI8713	4.77	10.49	8.45	8.44	8.04	1.41	4.23	3.56	2.38	2.90	6.18	14.72	12.01	10.83	10.93
HI1563,	2.92	8.94	7.53	5.53	6.23	1.09	3.25	2.31	3.62	2.57	4.00	12.19	9.84	9.16	8.80
HI1544	3.09	9.19	5.63	5.34	5.81	1.64	3.82	2.57	3.30	2.83	4.74	13.01	8.20	8.63	8.65
HI1531	2.96	10.61	6.70	7.53	6.95	1.07	4.71	2.97	2.41	2.79	4.03	15.32	9.68	9.94	9.74
GW366	3.61	9.72	8.59	6.46	7.10	1.45	4.52	2.63	3.78	3.09	5.05	14.23	11.22	10.25	10.19
LOK1	2.74	7.57	6.77	6.45	5.88	2.15	4.78	3.36	3.40	3.42	4.89	12.35	10.14	9.84	9.30
NARMADA14	3.00	9.80	8.30	7.88	7.24	1.98	5.43	3.18	4.04	3.66	4.98	15.24	11.48	11.91	10.90
Mean B	3.38	9.51	7.03	6.87		1.55	4.46	2.92	3.20		4.92	13.97	9.94	10.07	
Factors	**C.D.**		**SE(d)**		**SE(m)**	**C.D.**		**SE(d)**		**SE(m)**	**C.D.**		**SE(d)**		**SE(m)**
Factor(A)	0.78		0.24		0.17	0.75		0.23		0.16	1.45		0.44		0.31
Factor(B)	0.58		0.29		0.20	0.61		0.30		0.21	0.71		0.35		0.25
Factor(B)at same level of A	1.28		0.57		0.50	N/A		0.60		0.49	1.70		0.70		0.93
Factor(A)at same level of B	1.32		0.59		0.42	N/A		0.61		0.43	1.92		0.79		0.56

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

3.3 P use Efficiency

The statistical analysis revealed that different quantities of nitrogen application have a considerable

There weresignificant differences in agronomic use efficiency based on P application observed amongst varieties of wheat and fertilizer treatments. The range of AUE was found in between 8.36 (HI8737) to 40.09 %(GW366) among all the treatments. The mean AUE was higher in reducedphosphatic fertilizer dose treatment followed by reduced nitrogen dose fertilizer treatment and Normal dose treatment (Table 4).Among the varieties grown in full dose of N & P treatment, highest AUE was found in HI8663 (27.45%) and the lowest AUE was found in HI 8737 (8.36%). Among the varieties grown in half dose of N fertilizer treatment, highest AUE was observed in HI8663 (37.08 %) followed by HI1563 (35.54%) and among the varieties grown in half dose of P, highest AUE was found in GW366 (40.09%) followed by LOK1 (37.93 %). Among all the treatments, highest AUE was observed in GW366 (40.09%) in reduced P dose and it was followed by Lok1(37.93%) in reduced P dose treatment and the lowest AUE was observed in HI8737 (8.36%) in normal dose treatment (Table 4).

There were significant differences in APR observed between varieties of wheat and fertilizer treatments. The range of APR was found in between 8.55(HI1544) to 23.82 %(HI8713) among all the treatments. Among the treatment, the mean APR was the highest in reduced phosphatic fertilizer dose treatment followed by Normal dose treatment, reduced nitrogen dose fertilizer treatment (Table 4).Among the varieties grown in full dose of N & P treatment, the highest APR was found in HI1531 (15.25%) and the lowest APR was found in HI1563 (12.12 %). Among the varieties grown in half dose of N fertilizer treatment the highest APR was observed in NARMADA14 (11.84%) followed by HI8713 (10.73%) and among the varieties grown in half dose of P, the highest APR was found in HI8713 (23.82%) followed by GW366 (22.27 %). Among all the treatments, the highest APR was observed in HI8713 (23.82%) followed by NARMADA14 (22.79%) in reduced P dose treatment and lowest APR was observed in HI1563 (9.09%) in reduced N dose treatment. Across all nutrient treatments, APR in the wheat varieties followed the following trends

NARMADA 14 >HI8713 >GW366 >HI1531 > LOK1 >HI8737 >HI1563>HI8663>HI1544(Table 4).

There were significant differences in P-PUE observed between varieties of wheat and fertilizer treatments and the range of PUE was found in between 44.46 (HI8713) to 394.76 % (GW366). Among all the treatment the mean PUE was highest in reduced nitrogen fertilizer dose treatment followed by Normal dose treatment, reduced P dose fertilizer treatment. Among the varieties the highest PUE was found in GW366 (394.76%) followed by HI8663 (389.84%) HI8663, HI1563 genotypes with high P-AUE values had reduced grain P uptake and grain yield at the stressed P level. As a result, these genotypes were inefficient at using P. The PPUE data reveal that low yielding genotypes with high PPUE values at stressed P levels were P efficient, whereas low values with ample P supply were not. As a result, these genotypes are more suited to both high and low P environments because they efficiently obtain and utilize P for optimal grain production.

[14]However, uptake efficiency is associated with root architecture and physiological characteristics [20]. HI8663, HI1563 genotypes with high P-AUE values had reduced grain P uptake and grain yield at the stressed P level. As a result, these genotypes were inefficient at using P. The PPUE data reveal that low yielding genotypes with high PPUE values at stressed P levels were P efficient, whereas low values with ample P supply were not. As a result, these genotypes are more suited to both high and low P environments because they efficiently obtain and utilise P for optimal grain production. However, uptake efficiency is associated with root architecture and physiological characteristics [14].Among wheat genotypes, variation in P uptake, which was linked to variability in P harvest index, was less strongly connected to genotypic variation in grain production than was variation in P utilization efficiency (PHI). Breeding has increased yield, although genetic gains in total

P uptake have not been very important. Instead, improvements in PUE have been linked to increases in Putilization efficiency and PHI [8].

According to the findings, wheat genotypes differ greatly in terms of their P need for growth and grain output, and genotypes that explore for P better under stress conditions can withstand P deficiency stress. As a result, genotypes that produce more grain per kilogramme of absorbed P are P efficient. HI8713, NARMADA14 genotype generated more grain per kilogramme of absorbed P. This study's findings may be useful in developing genotypes with enhanced P use under P deficient conditions.

Table 4 Effect of N&P on phosphorus use efficiency of wheat genotypes

	Agronomic use efficiency (%)				Apparent phosphorus 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	27.45	37.08	36.29	33.61	14.74	9.35	16.27	13.45	356.23	389.84	228.43	324.83
HI8737	8.36	33.99	33.59	25.31	13.78	10.54	17.23	13.85	60.74	319.52	197.38	192.54
HI8713	19.04	10.60	13.66	14.43	14.62	10.73	23.82	16.39	130.74	127.51	44.46	100.90
HI1563	27.47	35.54	28.52	30.51	12.12	9.09	19.55	13.59	227.55	321.48	182.92	243.98
HI1544	11.62	15.44	28.15	18.40	12.94	8.55	16.25	12.58	90.73	334.02	95.06	173.27
HI1531	20.02	11.95	24.66	18.88	15.25	9.88	19.22	14.78	132.06	251.74	62.28	148.69
GW366	25.76	30.48	40.09	32.11	14.15	10.17	22.27	15.53	182.06	394.76	137.45	238.09
LOK1	16.03	18.32	37.93	24.09	12.27	9.76	20.11	14.05	130.71	388.90	92.02	203.87
NARMADA14	19.26	23.91	30.56	24.58	15.15	11.84	22.79	16.59	127.29	258.33	104.90	163.51
Mean B	19.45	24.15	30.38		13.89	9.99	19.72		159.79	309.56	127.21	
Factors	**C.D.**	**SE(d)**		**SE(m)**	**C.D.**	**SE(d)**		**SE(m)**	**C.D.**	**SE(d)**		**SE(m)**
Factor(A)	1.83	0.40		0.28	2.60	0.56		0.40	39.50	8.53		6.03
Factor(B)	1.79	0.86		0.61	1.26	0.61		0.43	54.99	26.49		18.73
Factor(B)at same level of A	3.37	1.49		0.84	2.83	1.05		1.19	99.64	45.88		18.09
Factor(A)at same level of B	3.30	1.46		1.03	3.07	1.14		0.80	95.75	44.09		31.17

T_1Control, T_2==100% (N+P+K) T_3= 50% N+ 100% (P+K), T_4 =50%P+100%N+K

4. CONCLUSION

a. The variety HI 8713 of wheat studied had the highest total phosphorus uptake and apparent phosphorus recovery.
b. Of the four nutrient treatments, the recommended doses of N and P T_2 outperformed all nine varieties of wheat in terms of various efficiency parameters, while T_1 was the least effective.
c. In the black cotton soil the genotypes HI8713 and NARMADA14, which have superior P uptake, could be employed as P-efficient cultivars.

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ABBREVIATION

Table 5

Abbreviation	Detail	Abbreviation	Detail
ADP	Adenosine diphosphate	**DW**	Dry weight
APR	Apparent phosphorus recovery	**EC**	electrical conductivity
APUE	Agronomic physiological use efficiency	**EC**	Electronic conductivity
ATP	Adenosine triphosphate	***et al*.,**	And co-workers /and others
CHL	Chlorophyll	**FAS**	Foreign agricultural services
Chl.	chlorophyll	**Fig.**	Fig.
CRI	Critical root initiation	**FUE**	Fertilizer Use efficiency
DAP	Di ammonium phosphate	**FW**	fresh weight
DAS	Days after sowing	***i.e.***	That is
DMSO	Dimethyl sulfoxide	**K**	Potassium
DMSO	Di methyl sulphoxide	**N**	Nitrogen
DNA	Deoxyribonucleic acid	**OC**	Organic carbon

PPUE	Phosphorus physiologic use efficiency	**P**	Phosphorous
PUE	Physiological use efficiency	**PAUE**	Phosphorus agronomic use efficiency
RDN	Recommended dose of fertilizer	***viz.,***	Namely
RNA	Ribonucleic acid	**WUE**	Water Use efficiency
RWC	Relative water content	**ATP**	Adenosine triphosphate
SOC	Soil Organic Carbon	**USDA**	United state department of agriculture

APPENDIX

Table 6

Source of Variation	**DF**	**P% straw**	**P Uptake (kg/ha**			**Nutrient use efficiencies by P**		
			Grain	**Straw**	**Total**	**AUE**	**ANR**	**PUE**
Replication	1							
Factor A	3	0.001				541.61		
Error(a)	3	0	114.551	25.732	247.56	1.41	94.42	132,936.86
Factor B	8	0	0.505	0.473	1.728	260.85	2.43	815.27
Interaction A X B	24	0	4.096	0.878	5.39	89.41	5.67	30,459.34
Error(b)	32	0	1.244	0.397	1.421	2.22	1.52	10,964.71
Total	71		0.325	0.359	0.487		0.62	766.17

Factor A Main plot (fertilizer doses) and factor B Sub plot(varieties).