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## Research Article

# Exploiting Selected Obsolete Wheat Cultivars of Pakistan for Climate Smart, Low Phosphorus Input Agriculture

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## ABSTRACT

Identifying genotypes that are efficient in phosphorus (P) help reduce the input of costly P fertilizers and promote environmental health. P efficiency of five selected obsolete wheat cultivars, viz. MEXIPAK-65, INDUS-66, PAK-70, PARI-73, ZA-77 was exploited in a thrice replicated randomized complete block design field study, involving TJ-83 as control, on a P deficient soil supplied without or with P (0 and 90 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>, respectively). Results revealed that the wheat genotype PARI-73 had the highest seed index, followed by PAK-70 which received no P fertilizer, and followed by TJ-83 at adequate P supply. Likewise, it also produced maximum grain yield at no P supply, however, TJ-83 produced maximum grain yield followed by ZA-77 at adequate P level. The straw yield of ZA-77 was highest at no P supply, while at adequate P supply TJ-83 offered maximum straw yield followed by ZA-77. Grain and straw P concentration was noted maximum in case of MEXIPAK-65 at no P supply, while for ZA-77 at adequate P supply. The grain and straw P accumulation of all the wheat varieties was statistically similar at no P supply, however, it was maximum for TJ-83 at adequate P followed by ZA-77. The P-use-efficiency of PARI-73 was more than any wheat genotype while the P efficiency ratio of wheat varieties was maximum for Indus-66 and PAK-77 followed by MEXIPAK-65 and PARI-73. These results endorse that wheat genotypes differ for their P-use-efficiency and P utilization. The wheat genotype PARI-73 can be an ideal candidate for climate smart low P input agriculture

**Keywords:** Phosphorus, Wheat, Genotypic Variation, Climate Smart Agriculture.



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## INTRODUCTION

Phosphorous (P) is a vital plant nutrient which plays many key roles in the life of plants. Its impacts are of far most significance on natural as well as agricultural ecosystems, when compared to many other plant nutrients (Memon, 1996). Interestingly, plant roots can absorb very little quantity (up to 30%) of fertilizer P during initial growth phase, which reduces later (Manske et al., 2001).

The roles that P plays in the plants as one of the most vital plant nutrients include the proper growth and development of plants, supplied with its adequate amounts, which in turn ensures optimum yield of crops (Fageria and Baligar, 2008). It is also involved in energy transfer, complementing photosynthesis and respiration, improving root development and contributing to cellular processes (Khan et al., 2023). Hence, the dearth of P nutrition plays havoc with sustainable and profitable crop production (Vance et al., 2003). It has been reported that despite the application of P fertilizers in bulk amounts the P losses from the soils are even greater (Tilman et al., 2001). The pathways through which applied P is lost from soil which include precipitation into insoluble compounds, adsorption, leaching etc. (Jin et al., 2023).

The scarcity of P has been reported for almost one-third (30%) arable land around the globe and the global P reserves are estimated to be mined by 2050 (Vance et al., 2003). The available P status of most of the Pakistani soils (~90%) are reportedly inadequate and averaged to  $<10 \text{ mg kg}^{-1}$  (Memon, 1996). This is a very alarming situation especially for wheat (*Triticum aestivum* L.) crop which takes off almost half (~45%) of the fertilizer P consumed in Pakistan (Vishandas et al., 2006; GoP, 2023).

As a matter of fact, wheat is the most used staple food of world, including Pakistan where it occupies an area of 8.9 M ha and offers a production of ~26.0 M tons, with  $<2.9 \text{ Mg ha}^{-1}$  average yield (GoP, 2023). Nonetheless, the increasing population ever demands that the production of this very important staple food crop must be increased with time through all possible interventions and strategies (Albahri et al., 2023) while keeping the input cost at the bare minimum level, especially that of P fertilizers that are too costly these days.

The exploitation of genotypic variation to enhance P-use-efficiency has been the subject of many studies. The screening of existing gene-bank of crops and their species, particularly wheat, appeared to be the most promising tool for enhancing its production under low-input sustainable agriculture (Siddiqi and Glass, 1981; Fageria et al., 1997). The identification and development of P-use-efficient wheat genotypes possess a potential for improved crop yields under P deficiency stress (Bilal et al., 2018a; Bilal et al., 2018b).

The adoption of various crop species to several biotic and abiotic stresses is directly related to their existing variation and their efficiency to take up, translocate, accumulate, and utilize mineral nutrients. This is because crop genotypes and their different species vary in their potential to acquire nutrients from the rhizosphere and efficiently utilize the same. It is now widely recognized that crop genotypes and species possess varying capacities for the uptake and utilization of plant nutrients (Gahoonia and Nielsen, 1996; Romer and Schenk, 1998) and this variation can be effectively executed to develop nutrient-use-efficient genotypes. This strategy has been advocated as the most important tool to lower the input cost of highly unaffordable P fertilizers in developing countries.

As a matter of fact, obsolete wheat genotypes have been considered as the most classical breeding material that have the highest potential to cope with a variety of biotic and abiotic stresses, including nutrient deficiency stresses and hence effectively utilized to develop nutrient-use-efficient genotypes. This field study was conducted with the hypothesis that obsolete wheat genotypes of Pakistan may exhibit varying responses to P-deficiency stress, with certain genotypes displaying greater tolerance and adaptability.

## MATERIALS AND METHODS

The study was arranged in a two-factor split-plot Randomized Complete Block Design (RCBD) with three repeats. Factor (A) consisted of six wheat genotypes, namely MEXIPAK-65, INDUS-66, PAK-70, PARI-73, ZA-77 (all obsolete) and TJ-83 (modern wheat variety used as control) assigned in the main plots. Factor (B) comprised of two P doses: 0 (control) and  $90 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ , applied to the sub plots with  $120 \text{ N kg ha}^{-1}$ . Sowing was done at a seeding rate of  $125 \text{ kg ha}^{-1}$ . Entire P fertilizer and half of the recommended dose of N was applied at sowing through broadcasting followed by proper mixing in the soil. The leftover N was applied at first irrigation through broadcasting. Soil samples were collected from the experimental field prior to sowing at the depth of 0-20 cm for the analysis of various physical and chemical properties. The experimental soil was clay loam in texture, alkaline in reaction (pH: 7.7), non-saline (EC:  $0.74 \text{ dS m}^{-1}$ ), medium calcareous (14%  $\text{CaCO}_3$ ), and low in organic matter content (0.57%) and available P ( $2.3 \text{ mg kg}^{-1}$ ). Plants were harvested after 136 days of sowing when the crop reached at maturity stage, to record important traits, viz. seed index (1000-grain-weight) and grain and straw yield. The harvested plant samples were brought into the laboratory, washed with deionized water, oven dried, and ground into powder for the analysis of P content of grain and straw (Ryan et al., 2001). Furthermore, P-relations were determined as P-efficiency ratio (Gunes et al., 2006), P-use-efficiency (Siddiqi and Glass, 1981), and grain and straw accumulation of P (Zia-ul-hassan et al., 2011). The analysis of variance (ANOVA) of the data for various observations was done using Statistix version 8.1. The treatment means were compared using honestly significant difference test at alpha 0.05. The performance of obsolete wheat genotypes was compared with the control modern wheat genotype using Dunnett's Multiple Comparison with a Control.

## RESULTS

### Seed index (1000-grain weight)

Statistical data ANOVA showed that both the primary effects and their interactions were highly significant in terms of seed index production of wheat varieties (Table 1). The seed index was marginally (3.9%) higher in the case of

adequate P supply than in the case of control where no P was applied. According to Table 1, the highest obsolete wheat cultivars' seed index for PARI-73 was 14.2% more than the lower seed index for INDUS-66. Three obsolete wheat cultivars' seed index showed substantial differences from the control cultivar TJ-83, as established using Dunnett's Multiple Comparison with a Control, a two-sided method (DMCC). Three wheat cultivars not being used in modern agriculture had significantly different seed indexes than the control cultivar TJ-83. Whereas the seed indexes of the other two obsolete wheat varieties were nearly similar. It's interesting to note that PARI-73 generated a higher seed index (9.21%) than TJ-83.

Similarly, at inadequate P rate, the seed indices of TJ-83 and MEXIPAK-65 and INDUS-66 were found to be reasonably equivalent to TJ-83 when the control wheat cultivar, TJ-83, was compared to the performance of obsolete wheat genotypes.

Table 1. Seed index (1000-grain weight, g) of obsolete wheat cultivars as affected by genotypic variation at deficient and adequate levels of phosphorus.

Wheat cultivar	Phosphorus ( $P_2O_5$ kg ha <sup>-1</sup> )		Wheat cultivar mean
	00	90	
MEXIPAK-65	35.0ef	36.4de	35.7CD
INDUS-66	34.4f	36.2de	35.3D
PARI-73	39.0b	41.6a	40.3A
PAK-70	37.2cd	36.3de	36.8B
ZA-77	36.0de	36.3de	36.2BC
TJ-83	35.2ef	38.5bc	36.9B
Phosphorus mean	36.1B	37.6A	
	P	WC	P × WC
P-value	0.0000	0.0000	0.0000
HSD <sub>0.05</sub>	0.3032	0.8127	1.3621

Means followed by the same letters are alike at alpha 0.05.

### Grain yield

Grain yield was found to be greatly influenced by the major factors and their interactions, according to the p-values obtained from ANOVA (Table 2). When compared to the control, which received no P fertilizer, grain output was considerably higher (71.1%) when adequate P was applied. Table 2 shows that the maximum grain yield of obsolete wheat cultivars, PARI-73 was 18.5% higher than the lowest yield obtained by PAK-77. Based on two-sided DMCC, there was a substantial difference in the grain yield of four old wheat varieties when compared to the control cultivar TJ-83. ZA-77, an obsolete wheat cultivar, with a grain yield that was nearly identical to that of TJ-83. When obsolete wheat cultivars were compared to TJ-83 at the insufficient P-level, the results showed that, with the exception of PARI-73, which yielded noticeably less wheat when grown under P stressed conditions. Under P deficiency stress, there were no significant differences between any of the wheat cultivars (Table 2.)

### Straw yield

The main influence and its interaction were very significant in creating straw yield, as evidenced by the p values from the ANOVA (Table 2). When compared to control, which received no P fertilizer, straw yield increased by 34% when adequate P nutrition was supplied. The straw yield of five those varieties not used today, differed significantly from control. Comparing obsolete wheat genotypes to control cultivar TJ-83, the maximum decrease was observed in INDUS-66, while the least reduction was in the case of ZA-77 (Table 2). It was found, very surprisingly, that all of the wheat cultivars responded to P shortage stress in a similar way when the effectiveness of TJ-83 in yielding straw at low P nutrition was contrasted with that of obsolete wheat cultivars (Table 2).

### Grain phosphorous concentration

The main effect and its interaction were shown to have a highly significant impact on grain P concentration, as evidenced by the p-value obtained from the ANOVA as shown in Table 3. As anticipated, grain P concentration significantly increased (110%) when adequate P nutrition was applied compared to control, which received no P fertilizer. The highest grain P content of MEXIPAK-65, an obsolete cultivar, is shown in Table 3 and was found to be 29.4% greater over lowest phosphorus content. It was interesting to note that, according to Table 3, the grain P content of TJ-83 was less than that of the remaining three obsolete wheat cultivars, but MEXIPAK-65 and ZA-77 had

higher grain P content than TJ-83. When the performance of obsolete wheat cultivars with inadequate P nutrition was compared to TJ-83, PARI-73 and PAK-77 had comparable grain P content to TJ-83 (Table 3).

Table 2. Grain and straw yield (Mg ha<sup>-1</sup>) of obsolete wheat cultivars as affected by genotypic variation at deficient and adequate levels of phosphorus.

Wheat Cultivars (WC)	Grain P concentration (mg g <sup>-1</sup> )			Straw P concentration (mg g <sup>-1</sup> )		
	Phosphorus (P <sub>2</sub> O <sub>5</sub> kg ha <sup>-1</sup> )		WC mean	Phosphorus (P <sub>2</sub> O <sub>5</sub> kg ha <sup>-1</sup> )		WC mean
	00	90		00	90	
MEXIPAK-65	2.20fg	3.25cd	2.72BC	4.97e	5.95cde	5.46BC
INDUS-66	2.27fg	3.21cd	2.74BC	4.83e	5.94cde	5.38C
PARI-73	2.50ef	3.76bc	3.12AB	5.15e	7.11abc	6.13AB
PAK-70	2.16fg	3.04de	2.60C	5.11e	6.56bcd	5.84BC
ZA-77	1.99fg	4.18ab	3.08AB	4.97e	7.19ab	6.08ABC
TJ-83	1.79g	4.64a	3.21A	5.44de	8.10a	6.77A
P mean	2.15B	3.68A		5.08B	6.81A	
	P	WC	P × WC	P	WC	P × WC
P-value	0.0000	0.0013	0.0000	0.0004	0.0126	0.0004
HSD <sub>0.05</sub>	0.1543	0.4136	0.6931	0.7116	1.1926	0.7116

Means followed by the same letters are alike at alpha 0.05.

Table 3. Grain and straw phosphorous concentration (mg g<sup>-1</sup>) of obsolete wheat cultivars as affected by genotypic variation at deficient and adequate levels of phosphorus.

Wheat Cultivars (WC)	Grain P concentration (mg g <sup>-1</sup> )			Straw P concentration (mg g <sup>-1</sup> )		
	Phosphorus (P <sub>2</sub> O <sub>5</sub> kg ha <sup>-1</sup> )		WC mean	Phosphorus (P <sub>2</sub> O <sub>5</sub> kg ha <sup>-1</sup> )		WC mean
	00	90		00	90	
MEXIPAK-65	0.69e	1.33ab	1.01A	0.69e	1.33ab	1.01A
INDUS-66	0.58f	1.11c	0.84D	0.58f	1.11c	0.84D
PARI-73	0.52h	1.06d	0.78E	0.52h	1.06d	0.78E
PAK-70	0.53gh	1.06d	0.79E	0.53gh	1.06d	0.79E
ZA-77	0.56fg	1.37a	0.97B	0.56fg	1.37a	0.97B
TJ-83	0.55gh	1.30b	0.92C	0.55gh	1.30b	0.92C
P mean	0.57B	1.20A		0.57B	1.20A	
	P	WC	P × WC	P	WC	P × WC
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HSD <sub>0.05</sub>	9.183	0.0246	0.0412	9.183	0.0246	0.0412

Means followed by the same letters are alike at alpha 0.05.

### Straw phosphorous concentration

The p-value from ANOVA at alpha 0.05 showed that the only factors that significantly affected the concentration of P in straw were varying P levels; the interaction between P × wheat cultivars and other wheat cultivars was not significant (Table 3). The concentration of straw P increased by 125% when adequate P nutrition was supplied, as opposed to the control where no P fertilizer was applied. All wheat cultivars had equal P concentrations across two P-levels; no statistically significant difference was observed. The concentration of P in straw of four obsolete wheat types was considerably lower than that of control cultivar TJ-83, as determined by two-sided DMCC. Whereas the concentration of straw P in one obsolete wheat cultivar, PAK-70, was similar. Table 3 shows that in the cases of MEXIPAK-65 and PARI-73, the greatest reduction in straw P was noticed, whereas the cases of INDUS-66 and ZA-77 showed the lowest reduction. All of the wheat cultivars' straw P content under inadequate P nutrition were statistically comparable to TJ-83 (Table 3).

### Grain phosphorous accumulation

The p-values obtained from ANOVA at alpha 0.05 indicated that primary influence and the highly significant interactions on the grain P accumulation of wheat cultivars as shown in Table 4. Grain P accumulation was significantly enhanced (195%) with adequate P nutrition over control which received no P fertilizer. Table 4 showed the highest accumulation of P in wheat grains of the varieties not used in modern-day agriculture, ZA-77 which was

observed to be 31.8% larger PAK-70's lower bioaccumulation in grains. Compared to control, the grain P accumulation of four obsolete wheat genotypes was much lower. The instance of PAK-70 showed the greatest reduction in grain P accumulation, whereas the case of ZA-77 showed the least reduction (Table 4). It was shown that the wheat cultivars statistically resembled the control wheat cultivar TJ-83 under inadequate P nutrition, which produced grain P buildup (Table 4).

Table 4. Grain and straw phosphorous accumulation (mg plant<sup>-1</sup>) of obsolete wheat cultivars as affected by genotypic variation at deficient and adequate levels of phosphorus.

Wheat Cultivars (WC)	Grain P concentration (mg g <sup>-1</sup> )			Straw P concentration (mg g <sup>-1</sup> )		
	Phosphorus (P <sub>2</sub> O <sub>5</sub> kg ha <sup>-1</sup> )		WC mean	Phosphorus (P <sub>2</sub> O <sub>5</sub> kg ha <sup>-1</sup> )		WC mean
	00	90		00	90	
MEXIPAK-65	12.7e	34.8c	23.72B	13.7c	40.2b	26.90B
INDUS-66	10.6e	27.6d	19.10C	13.6c	52.0ab	32.82AB
PARI-73	10.2e	28.5d	19.35C	14.3c	52.0a	33.37AB
PAK-70	10.5e	27.0d	18.78C	13.8c	56.5a	35.17A
ZA-77	11.6e	37.9b	24.75AB	16.5c	58.2a	37.37A
TJ-83	11.8e	41.2a	26.0A	16.5c	62.6a	39.5A
P mean	11.1B	32.8A		14.7B	53.7A	
	P	WC	P × WC	P	WC	P × WC
P-value	0.0000	0.0000	0.0000	0.0000	0.0016	0.0114
HSD <sub>0.05</sub>	0.5714	1.5315	2.5668	2.6791	7.1804	12.034

Means followed by the same letters are alike at alpha 0.05.

### Straw phosphorous accumulation

The results of the ANOVA showed that the only factors that significantly affected straw P accumulation were variations in P levels; the interaction between P and wheat cultivar and wheat cultivar alone was not significant (Table 4). When compared to the control, which received no P fertilizer, the accumulation of straw P was considerably increased by (265%) by adequate P nutrition. With regard to obsolete wheat genotypes, Table 4 showed the highest straw phosphorus bioaccumulation of ZA-77 was 38.9% higher over lowest straw P accumulation of MEXIPAK-65. Four obsolete wheat genotypes had much less straw phosphorus accumulation than the control wheat genotype TJ-83, according to two-sided DMCC. But only one obsolete wheat cultivar's straw P accumulation was similar to that of TJ-83. Comparably, all wheat cultivars' P accumulation in straw produced with inadequate P nutrition is statistically similar to that of the control wheat cultivar TJ-83 (Table 4).

Table 5. Phosphorus efficiency (g<sub>2</sub> mg<sup>-1</sup>) of obsolete wheat cultivars as affected by genotypic variation at deficient and adequate levels of phosphorus.

Wheat Cultivars	Phosphorus (P <sub>2</sub> O <sub>5</sub> kg ha <sup>-1</sup> )		Wheat Cultivar Mean
	00	90	
MEXIPAK-65	26.4c	19.5e	26.95E
INDUS-66	31.9b	22.1de	26.95D
PARI-73	38.3a	25.4cd	31.88A
PAK-70	37.3a	24.0cd	30.65AB
ZA-77	35.5a	20.2e	27.85CD
TJ-83	35.0ab	24.5cd	29.75BC
P- level mean	34.1A	22.6B	
	P	WC	P × WC
P-value	0.0000	0.0000	0.0003
HSD <sub>0.05</sub>	0.7612	2.0401	3.4192

Means followed by the same letters are alike at alpha 0.05.

### Phosphorous-use-efficiency

The p-value from ANOVA showed that the main effects and their interaction were significant in determining the wheat cultivars' grain P-use-efficiency (Table 5). Grain P-use efficiency was much (50%) higher with adequate P compared

to control where no P was supplied to wheat crop. Of the extinct wheat genotypes, PARI-73 had the highest grain P-use-efficiency. Two obsolete wheat genotypes had P-use-efficiency values that were significantly lower than the control genotype. On the other hand, Table 5 shows that P-use-efficiency of three obsolete genotypes of wheat: PARI-73, PAK-70 and ZA-77. The grain P-use-efficiency of obsolete wheat cultivars was found to be statistically similar for PARI-73, PAK-70, and ZA-77 when they were compared to TJ-83 with insufficient P nutrition, but considerably different for MEXIPAK-65 (Table 5).

### Phosphorous efficiency ratio

Figure 1 shows the P efficiency ratio (PER) for all the wheat cultivars. Six wheat varieties had an average PER of 0.603 which was less than the 0.646 average of five obsolete wheat cultivars. As anticipated, the results (Figure 1) clearly demonstrated that the average PER of five those varieties that are not used anymore and the PER of the four obsolete genotypes were greater than those of the cultivar TJ83, which served as the control. This was not the case, though, for ZA-77, whose PER was lower than the mean PER of the five extinct wheat varieties. It was interesting to observe that INDUS-66 and PAK-70 had the higher PER, while PARI-73 and ZA-77 had the lowest PER. Additionally, the data indicated that the TJ-83 control wheat variety had the significantly lower PER. Furthermore, Figure 1 shows that the average PER of all wheat genotypes was higher than the grain P-use-efficiency of two wheat genotypes.

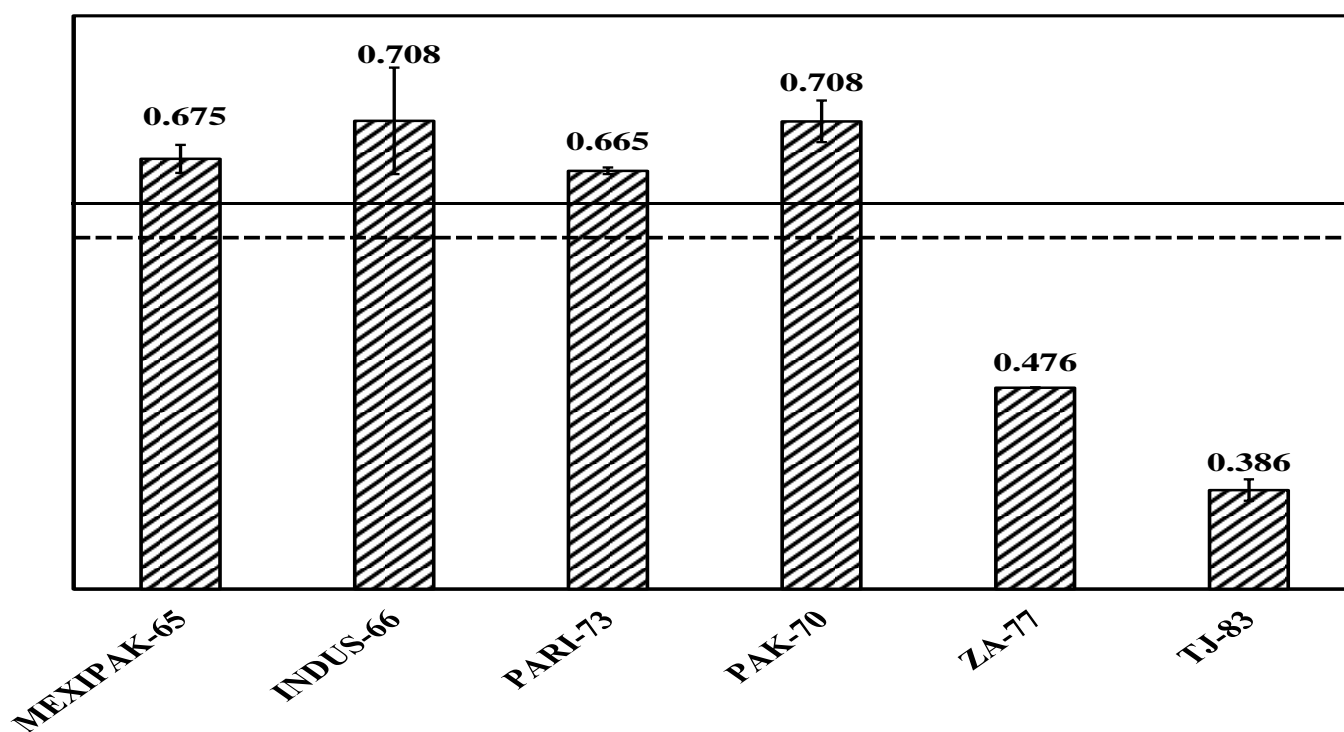


Figure 1. The P efficiency ratio (PER) of different wheat cultivars. The average PER of all six wheat cultivars (0.603 presented as a dotted line) was lower than the average PER of five obsolete wheat cultivars (0.646 presented as a solid line).

### DISCUSSION

The present field experiment was conducted to determine P-use-efficiency of some Pakistani wheat cultivars that are now obsolete. The results of the study validated earlier research and showed the importance of P nutrition of wheat, presence of genotypic heterogeneity across different genotypes of wheat, and the possible impact of obsolete genotypes of P-use-efficiency. Numerous significant research continued to focus on the function of P in wheat nutrition. One of the most significant essential plant nutrients, phosphorus which is necessary for plant growth and development and assures optimal crop yield (Fageria and Baligar, 2008).

Tables 1 through 5 and Figure 1 illustrate that the genotypic variation across different wheat cultivars for the majority of their growth parameters yield response under P deficiency stress. Previous research has shown that wheat is the world's crop that uses the most P and depends on P reserves to yield high. In low P-input systems, the highest potential wheat production is ensured by the selection of P-efficient genotypes. As a result, it is imperative that wheat

genotypes which are P-efficient should be selected keeping in mind some considerations like feasibility and financially sensible strategy (Altin and Frey, 1990). When plants adapt to a nutrient stress state, genotypic variety and their capacity to absorb, translocate, accumulate, and use nutrients are critical factors. The ability of crop genotypes and their species to absorb and use plant nutrients varies, as is now widely known (Gahoonia and Nielsen, 1996; Romer and Schenk, 1998). The ability of different wheat genotypes to obtain P from applied fertilizer, the amount of P needed to produce a given unit of yield, and their resilience to P deficiency stress are all different (Yaseen et al., 1998). The degree of P uptake differs significantly among genotypes of wheat (Gahoonia and Nielsen, 1996). According to Liu et al. (1997), P-efficient wheat genotypes produced 8-10 times as much biomass as inefficient ones. Anwar et al. (2016) found that increasing the P fertilizer dose up to 90 kg P ha<sup>-1</sup> improved the growth, yield and P-relations of wheat. Due to genotypic variation, wheat's P-uptake was somewhat greater over other crop species (Sandana and Pinochet, 2016). The findings of the present field experiment support previous conclusions and provide a workable answer by pointing out a few obsolete wheat genotypes that can be successfully adapted to a low-P, sustainable wheat production scenario.

## CONCLUSION

These findings emphasize the importance of P nutrition in wheat and demonstrate the presence of genotypic variation among wheat varieties in their efficiency of P utilization. The wheat genotype PARI-73 can be an ideal choice for climate smart low P input agriculture.

## AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Zia-ul-hassan; study execution and data collection: Fozia Naz Memon, Bilawal Hussain Shah; analysis and interpretation of results: Zia-ul-hassan, Naheed Akhter Talpur, draft manuscript preparation: Zia-ul-hassan, Fozia Naz Memon, Inzamam Jamali, Khalid Hussain Talpur. All authors reviewed the results and approved the final version of the manuscript.

## COMPETING OF INTEREST

The authors declare no competing interests.

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