Association between various yield contributing traits of wheat (*Triticum aestivum* L.) at different levels of phosphorus

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Abstract: Wheat (*Triticum aestivum* L.) is third important cereal crop worldwide which is used for food and feed. Phosphorus is an important macro-nutrient for plant growth and productivity and its low concentration causes growth limiting condition in wheat. Application of phosphorus containing fertilizers not only increases cost of production but also causes environmental issues so, it is need of era to select wheat genotypes with better phosphorus uptake and utilization efficiency. In current study 50 wheat genotypes were screened for their response against three different phosphorus levels (0, 100 and 200 mg of P/kg of soil) in RCBD factorial experimental design. Data of nine yield related morphometric traits was collected. The recorded data was subjected to analysis of variance to check its significance. Varieties differ genetically from each other in different environments. ANOVA results indicates the presence of genotypic variability for almost all of the studied traits. Correlation analysis reveals that at low phosphorus level productive tillers, spike weight, thousand grain weight, biological yield and single head yield are yield contributing traits. The present study will be helpful to improve wheat cultivars for phosphorus deficient conditions.

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Introduction:

Bread wheat (*Triticum aestivum* L.) is third most widely grown cereal crop after maize and rice. In temperate regions wheat is primary cereal crop and the staple food of 40% world population (FAO, 2016). Wheat accounts for 30% of global cereal grains production of which 18% is internationally traded. It provides 20% calories around the globe in human food (Khanzada *et al.*, 2012). Wheat is a dominant cereal crop of developing countries including Pakistan. In Pakistan wheat is cultivated in rain fed and irrigated areas. It is used not only for food but also as feed and industrial material, as it is an important crop for food and feed in Pakistan. In Pakistan wheat is on top in all crops grown with respect to crop production and area under cultivation. It contributes 2% in GDP of Pakistan. Wheat grown area and production was 9.26 million hectare and 25.48 million tons respectively in cropping year 2025-16 (Pakistan Economic Survey, 2015-16).

Global population is growing quickly demanding production of surplus wheat to overcome food shortage issues. Nevertheless, wheat contributing significantly in Pakistan's economy, however, it can be further raised. Several biotic and abiotic reasons are associated with plant physiological changes. Wheat yield is affected substantially by several stresses and phosphorous deficiency is one of them. Deficiency may raise due to adsorption, lesser application, soil acidity/sodicity, microbial immobilization, and poor uptake or use efficiency. In macronutrients, phosphorous is important because of its association with high productivity as it plays vital role in photosynthesis, storage and transfer of energy, cell division, respiration and other mechanisms in plant like it helps seedlings and roots to develop rapidly, improve winter hardness, promotes uniform and early heading, seed formation and seed quality and improves water use efficiency as well (Ali *et al.*, 2014). The main source of phosphorus containing fertilizers is rock phosphate which is naturally occur as rock phosphate. Phosphorus natural resources are depleting quickly but utilization is increasing at an annual rate of 3%. Only Morocco is contributing approximately 40% of the world's production. A recent study summarized that phosphorous natural resources will deplete by 2050 (Gaxiola *et al.*, 2011) and the alternate means will be insufficient to overcome this gap. Furthermore, wheat has less recovery of applied phosphorous as compared to other cereals. Rice and maize have 14% and 18% recovery, whereas wheat has only 10% (Su *et al.*, 2009). This suggest high phosphorous requirements of wheat for better production. So, it the important need of time to develop the verities with better phosphorus uptake and utilization efficiency. Genetic variation present in wheat germplasm can be exploited to overcome deficiency issues.

Wheat genotypes extensively vary in their phosphorus uptake and utilization efficiency under underprovided environments. This inconsistency can be exploited to enhance wheat production and reduce production cost through reduced but efficient phosphorous use (Yaseen *et al*., 2003). Wheat Genotypes behaves differently in phosphorus deprivation conditions like change in root morphology and architecture, association with fungi (Arbuscular mycorrhizae), extrusion of organic acids (phosphatases) or proton to soil which lower down the soil pH which makes the phosphorus available to plant (Balemi and Negisho, 2012). Integration of conventional breeding and advance molecular techniques can be deployed to develop varieties with high phosphorous efficiency and better performance. Current study will be aimed at Screening of plant material at dissimilar phosphorus treatments and evaluation of characters association.

Material and methods:

Soil phosphorus determination

Total available phosphorus was determined using sodium bicarbonate method (Olsen *et al.,* 1954). Five grams of air-dry soil was taken in a flask and mixed with 100 mL of $NaHCO_3$ (0.5 M). Flask was shaken at 300 rpm for 30 minutes. One control flask was also included. Then 10 mL filtrate was pipetted out and taken into another flask after solution filtration with Whatman No. 40 filter paper. The pH was adjusted to 5.0. Distilled water was added to make-up the volume about 40-mL and 8 mL reagent B was added to make-up 50 mL volume. This final solution was used to determine phosphorous using spectrophotometer measuring absorbance at 882 nm wavelength. Blank consisted of all reagents/chemicals without soil. Absorbance of standards and samples was noted. The seed for fifty different wheat varieties and lines were collected from Cereal Research Program, PBG department, UAF. Table 1 denotes genotypes used in this study.

Table 1. Wheat genotypes

Sr. NO	Genotype	Sr. NO	Genotype
1	MF-1	26	SULEMAN 96
2	MF-2	27	SHAHEEN 94
3	MF-3	28	KOHSAR 95
4	MF-4	29	BAKHTAAWAR 93
5	MF-5	30	9867
6	NAX1 5020-7	31	CHAKWAL 86
7	NAX1 5020-27	32	CHAKWAL 50
8	NAX1 5907	33	1031
9	NAX2 5004	34	KRICHAUFF
10	NAX2 5042	35	1255
11	NAX2 5924	36	WAL 23
12	KHARCHIA 65	37	UJALA
13	STW 139	38	PUNJAB 11
14	STW 135	39	978
15	SEHAR 2006	40	ZA-1
16	MANTHAR 2003	41	GALAXY
17	IQBAL 2000	42	AAS 11
18	INQLAB 91	43	ZA-2
19	LU 26	44	ZA-4
20	PASBAN 90	45	LINE 1
21	FAISALABAD 83	46	9494
22	KOH E NOOR 83	47	LINE 2
23	ROHTAS 90	48	34ESWYT-13-14/146
24	WATAN	49	34ESWYT-138
25	NOSHEHRA 96	50	ZA-6

Wheat genotypes were sown in field in three different plots containing different Phosphorus levels (P0, P100 and P200 mg/Kg soil). Plant material was sown on December 11, 2016 and after field data measurements harvesting was carried out on April 25, 2017. Seeds were sown in lines with the help of Dibbler keeping line × line and plant × plant distance 22.5 cm and 15 cm respectively. Factorial randomized complete block design was followed with three repetitions. Moreover, efforts were done to implement proper production technology. Three plants were selected in each row with colored tapes for data recording in each replication. All parameters of data were taken from those selected plants. At appropriate times, data of nine morphometric traits was recorded i.e. plant height (PH), spike length (SL), productive tillers per plant (PT), spikelets per spike (NOS), spike weight (SW), number of grains per spike (NOG), 1000-grain weight (TGW), grain yield per plant (GYP) and harvest index (hi).

Average data for 50 genotypes under each experimental unit, was subjected to analysis of variance (Steel *et al*., 1997) with "Statistix 8.1" to check the presence of variation among the genotypes. Average performance of genotypes was predicted through graphical representation. Same data set of each experimental unit was subjected to correlation analysis (Miller *et al.*, 1958) to check the association of yield with other traits of plant by using "R 3.1.0" software.

Results and Discussion:

According to results traits in plant like plant height, number of productive tillers per plant, number of spiklets per spike, spike length, spike weight, number of grain per spike, thousand grain weight, grain yield per plant and harvest index with their probability ($p \leq 0.05$) at different levels of phosphorus. While in case of interaction of phosphorus and variety the productive tillers, spike weight and grain weight per spike differs significantly ($p \leq 0.05$). All other traits differs high significantly ($p \leq 0.01$) except grain number in one spike which is not significant at different levels of phosphorus. Spike length, number of spikelet, number of grains per spike, thousand grain weight and harvest index are non-significant in case of variety and phosphorus interaction.

To know the significance or non-significance of different plant traits, the Statitix 8.1 software was used for analysis of variance. The results show that in case of variety the plant height, productive tillers per plant, spike length, spikelet number, grains number/spike, thousand grain weight, yield of grain/plant, harvest index and grain weight/spike were significant with high rate ($p \leq 0.01$). Which shows that at least two verities are significantly different for these characters.

At different level of phosphorus the plant height, productive tillers, spike length, spikelet number/spike, spike weight, thousand grain weight and grain weight/spike are significantly higher ($p \leq 0.01$), spike length is significant ($p \leq 0.05$). It shows that at different level of phosphorus at least two verities are significantly different for these characters while the other characters like number of grains per spike and harvest index are non-significant at different levels of phosphorus. Phosphorus and variety interaction shows that plant height and grain yield per plant are highly significant ($p \leq 0.01$), productive tillers, spike weight and grain weight per spike are significant ($p \leq 0.05$). It shows that at least two verities are different in case of phosphorus and variety interaction, while spike length, grains number/spike, thousand grain weight and harvest index are not significant in variety and phosphorus interaction.

Results shows that varieties perform differently at different level of phosphorus that shows different wheat varieties differ in their performance at different phosphorus conditions (Yaseen *et al*., 2003). On the basis of average performance the genotype MF-1 is performed better for trait PH and LINE-2 for PT, MF-1 for PL and SL, Rohtas-90 for NOS, MF-3 for SW and NOG, 34-ESWYT-138 and Suleman-96 for TGW, 9867 for BY, Krichauff and Manthar-2003 for GY/P, 34ESWYT-13-14/146 for HI, and MF-3 for GW/Sp. Moreover under different phosphorus levels the characters PH, FLA, SL, NOS, NOG, TGW, BY, GY/P, GW/Sp are significantly different at all three phosphorus levels P0, P100 and P200 (Kaleem *et al*,. 2009; Ali *et al*,. 2014; Shafi *et al*,. 2015; Bashir et al., 2015). While SW and HI are significant at P0 and P100 but non-significant at P100 and P200 (Shafi *et al*,. 2015) and peduncle length is non-significant at all three phosphorus levels.

Table 1. ANOVA results of various traits

Source	PH	PT	SL	NOS	SW	NOG	TGW	GY/P	HI
Rep.	10.10**	0.45^{NS}	0.17^{NS}	0.18^{NS}	0.43^{NS}	147.2**	91.47**	1.22^{NS}	44.76**
Var.	142.2**	6.96**	8.87**	3.01**	0.63**	446.1**	63.44**	10.46**	104.4**
P.	219.1**	193.1**	22.39**	22.96**	2.38**	106.03^{NS}	437.0**	560.8**	78.72^{NS}
Var.*P.	54.77**	2.86*	1.46NS	1.72^{NS}	0.27*	82.32^{NS}	42.60^{NS}	8.22**	74.31^{NS}
Error	19.14	2.02	1.01	1.19	0.14	121.4	31.40	4.04	50.58
CV	5.28	19.12	8.96	5.62	14.26	18.74	17.38	19.27	16.79

Where: PH= plant height, PT= productive tillers, SL= spike length, NOS= number of spikelet, SW=spike weight, TGW= thousand grain weight, GY/P= grain yield per plant, HI= harvest index, NOG= number of grains per spike.

Table 1 Genotypic correlation at P0 phosphorus level

	PH	PT	SL	NOS	SW	NOG	TGW	GY/P	HI
PH	1								
PT	0.056^{NS}	1							
SL	0.63**	-0.44**	1						
NOS	0.19*	-0.48**	0.658**	1					
SW	0.17*	-0.33**	0.28**	0.369**	1				
NOG	0.11 ^{NS}	-0.25*	0.36**	0.52**	0.475**	1			
TGW	0.17*	0.32**	0.016 ^{NS}	0.11 ^{NS}	0.40**	-0.2**	1		
GY/P	0.04 ^{NS}	0.36**	0.10 ^{NS}	0.02 ^{NS}	0.65**	0.13 ^{NS}	0.49**	1	
HI	-0.39**	0.65**	-0.30*	-0.10 ^{NS}	0.28**	-0.3**	0.52**	0.86**	1

Where: PH= plant height, PT= productive tillers, SL= spike length, NOS= number of spikelet, SW=spike weight, TGW= thousand grain weight, GY/P= grain yield per plant, HI= harvest index, NOG= number of grains per spike.

Table 2 phenotypic correlation at P0 phosphorus level

	PH	PT	SL	NOS	SW	NOG	TGW	GY/P	HI
PH	1								
PT	0.12 ^{NS}	1							
SL	0.48**	-0.14 ^{NS}	1						
NOS	0.12 ^{NS}	0.06 ^{NS}	0.41**	1					
SW	0.15 ^{NS}	0.05 ^{NS}	0.20*	0.318*	1				
NOG	0.09*	-0.08 ^{NS}	0.34**	0.31**	0.37**	1			
TGW	0.18**	0.26**	0.03 ^{NS}	0.05 ^{NS}	0.30**	-0.22*	1		
GY/P	0.16*	0.56**	0.14 ^{NS}	0.21*	0.47**	0.12 ^{NS}	0.44**	1	
HI	-0.21*	0.12 ^{NS}	-0.18*	-0.5 ^{NS}	0.23*	-0.21*	0.3**	0.47**	1

Analysis of correlation used for measuring association strength among two diverse factors (Karim *et al.*, 2014). Correlation of genotype and phenotype of other traits of plant with yield of grains per plant calculated at different phosphorus levels i.e P0, P100 and P200. At P0 level of phosphorus results of genotypic correlation shows yield of grains in one plant is correlated positively by productive tillers, spike weight, thousand grain weight and harvest index while in case of phenotypic correlation at P0 level of phosphorus, it includes plant height and number of spikelet including above given traits.

At P100 level of phosphorus results of correlation of genotype shows yield of grains in one plant is correlated positively by productive tillers, spike weight, number of spikelet, thousand grain weight and harvest index while in case of phenotypic correlation at P100 level of phosphorus, it shows positive correlation with all above given traits except number of spikelet. At P200 level of phosphorus results of genotypic correlation shows grain yield per plant is positively correlated with productive tillers, thousand grain weight and harvest index while in case of correlation of phenotype at P200 level of phosphorus also same traits are positively correlated as given in genotypic correlation.

At P0= 0 mg P/kg of soil the genotypic correlation results show that per plant yield is positively correlated with productive tillers, spike weight and thousand grain weight. It shows that these are genotypic effects. In case of phenotypic correlation at P0= 0 mg P/kg of soil plant height, productive tillers, number of spikelet, spike weight, thousand grain weight and harvest index are positively correlated with grain yield per plant (Su *et al*,. 2009; EI-Mohsen *et al*,. 2011), it is the indication that these effects are due to combine effect of genotype and environment.

At P100=100 mg P/kg of soil the results of genotypic correlation show that yield of grains/plant is correlated positively by productive tillers, spikelets number, spike weight, thousand grain weight and harvest index. These effects are genotypic and increase in these character will ultimately increase the yield at P100= 100 mg P/kg of soil. Results of phenotypic correlation at P100=100 mg P/kg of soil shows that yield of grains/plant is correlated clearly by productive tillers, spike weight, thousand grain weight and harvest index. These are combine effects of genotype and environment.

At P200=200 mg P/kg of soil the result of genotypic correlation show that yield of grains/plant is clearly correlated by productive tillers, thousand grain weight & index of harvest. These effects are genotypic effects and increase in these traits will increase the grain yield per plant ultimately. Phenotypic correlation results At P200=200 mg P/kg of soil shows that productive tillers, thousand grain weight and harvest index are clearly correlated by yield of grains/plant. These are the combine effects of genotype and environment.

The results show that on the bases of quantitative data, the plant yield increased with increase in phosphorus levels. The association of yield contributing traits with yield is positive at all three levels of phosphorus. Moreover in low phosphorus conditions the traits productive tillers, spike weight and thousand grain weight are highly significant and positively correlated to yield so for these are the targeted traits for efficient phosphorus use cultivar with better productivity.

Table 3 Genotypic correlation at P100 phosphorus level

	PH	PT	SL	NOS	SW	NOG	TGW	GY/P	HI
PH	1								
PT	-0.16*	1							
SL	0.51**	-0.17*	1						
NOS	-0.02 ^{NS}	0.18*	0.194*	1					
SW	-.006 ^{NS}	-0.33**	0.14 ^{NS}	0.09 ^{NS}	1				
NOG	-0.07 ^{NS}	-0.33**	0.04 ^{NS}	0.26*	0.580**	1			
TGW	0.22*	0.06 ^{NS}	-0.1 ^{NS}	-0.2 ^{NS}	0.461**	-0.1 ^{NS}	1		
GY/P	0.01NS	0.67**	-0.1 ^{NS}	0.22*	0.20*	-0.1 ^{NS}	0.63**	1	
HI	-0.29*	0.31**	-0.3**	-0.17*	0.40**	0.07 ^{NS}	0.68**	0.605**	1

Table 4 Phenotypic correlation at P100 phosphorus level

	PH	PT	SL	NOS	SW	NOG	TGW	GY/P	HI
PH	1								
PT	0.02 ^{NS}	1							
SL	0.47**	-0.09 ^{NS}	1						
NOS	0.09 ^{NS}	0.13 ^{NS}	0.196*	1					
SW	0.05 ^{NS}	-0.14 ^{NS}	0.12 ^{NS}	0.099*	1				
NOG	-0.05 ^{NS}	-0.17*	0.06 ^{NS}	0.17 ^{NS}	0.483**	1			
TGW	0.16*	-0.03 ^{NS}	-0.03 ^{NS}	-0.02 ^{NS}	0.43**	-0.05 ^{NS}	1		
GY/P	0.11 ^{NS}	0.56**	0.02 ^{NS}	0.10 ^{NS}	0.247*	-0.02 ^{NS}	0.39**	1	
HI	-0.13 ^{NS}	0.08 ^{NS}	-0.2**	-0.19*	0.24*	0.01 ^{NS}	0.36**	0.49**	1

Table 5 Genotypic correlation at P200 phosphorus level

	PH	PT	SL	NOS	SW	NOG	TGW	GY/P	HI
PH	1								
PT	0.12 ^{NS}	1							
SL	0.53**	-0.09 ^{NS}	1						
NOS	-0.02 ^{NS}	-0.10 ^{NS}	0.19*	1					
SW	0.01 ^{NS}	-0.35**	0.13 ^{NS}	0.14 ^{NS}	1				
NOG	-0.16*	-0.28*	-0.03 ^{NS}	0.43**	0.419**	1			
TGW	0.22*	0.12 ^{NS}	0.26*	-0.05 ^{NS}	0.409**	-0.09 ^{NS}	1		
GY/P	0.09 ^{NS}	0.57**	-0.08 ^{NS}	-0.01 ^{NS}	0.05 ^{NS}	-0.06 ^{NS}	0.17*	1	
HI	-0.08 ^{NS}	0.23*	-0.22*	0.10 ^{NS}	0.01 ^{NS}	0.11 ^{NS}	0.30**	0.28**	1

Table 6 Phenotypic correlation at P200 phosphorus level

	PH	PT	SL	NOS	SW	NOG	TGW	GY/P	HI
PH	1								
PT	0.1 ^{NS}	1							
SL	0.47**	-0.7 ^{NS}	1						
NOS	-0.7 ^{NS}	-0.8 ^{NS}	0.14 ^{NS}	1					
SW	0.04 ^{NS}	-0.2**	0.13 ^{NS}	0.12 ^{NS}	1				
NOG	-0.1 ^{NS}	-0.24*	-0.02 ^{NS}	0.28**	0.36**	1			
TGW	0.18*	0.09 ^{NS}	0.23*	0.04 ^{NS}	0.33**	-0.1 ^{NS}	1		
GY/P	0.1 ^{NS}	0.52**	-0.07 ^{NS}	0.03 ^{NS}	0.04 ^{NS}	-0.1 ^{NS}	0.15*	1	
HI	-0.1NS	0.17*	-0.20*	0.08 ^{NS}	0.03 ^{NS}	0.10 ^{NS}	0.28**	0.25*	1

Conclusion

Results indicates the presence of genotypic variability for almost all of the studied traits. Correlation analysis revealed that at low phosphorus level productive tillers, spike weight and thousand grain weight were yield contributing traits.

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