Asian Journal of Chemistry Vol. 20, No. 4 (2008), 3249-3258

Genotype Variation for Phosphorus Uptake and Use Efficiency in Triticale on Calcareous Soil

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11 Winter triticale genotypes (5 lines and 6 released varieties) were evaluated and classified using Metroglyph analysis according to their grain yield performance and phosphorus uptake under both dryland and calcareous soil condition in Turkey. All genotypes were grown at a single rate of P (26 kg/ha). The grain yield of the lines and the combined genotypes were found to be significant ($p < 0.05$). TVD-17 in particular was found to have had the highest total P-uptake (15.62 %) and grain yield (3912 kg/ha). The grain yield, biological yield, P content in grain (%) and total P-uptake (%) averages of the lines were higher than that of the varieties. The results revealed that while TVD-17 appeared in the HGY-HP (high grain yield-high P-uptake) group, Tatlicak 97 variety was in the LGY-LP (low grain yield-low P-uptake) group.

Key Words: Genotype variation, Phosphorus uptake, Calcareous soil.

INTRODUCTION

Though the total amount of phosphorus in the soil may be high, however, its deficiency is a common mineral nutritional problem in both calcareous soils and acidic soils, due to its ability to link up chemically with such elements as calcium in alkaline soils and aluminum and iron in acidic soils[1]. Total soil P is often 100 times higher than the fraction of soil P available to crop plants[2]. Bates[3] estimated that P availability to plant roots is limited in nearly 67 % of cultivated soils, causing a more important constraint to world crop production than other deficiencies, toxicities and disease[4].

The application of phosphorus to the soil is necessary to ensure plant productivity in many agricultural systems. Nutrient inputs into production systems have increased as a result of the need for high yielding crops to

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sustain growing populations around the world. According to the IFA's findings[5] in 2004, world phosphate consumption was 37363.4 × 10^6 kg. When the P input from fertilizer exceeds the P output in a crop, P gradually accumulates in the soil[6], leading to many other environmental concerns, in particular pollution issues and surface runoff. Phosphorus fertilizer use efficiency (PUE) may average between 8 and 16 % due to phosphate management[7,8]. The objective of plant breeding is to encourage the growth of developed P efficient genotypes thus promoting high yields in P deficient soil conditions[1,9]. Differences in P uptake among varieties will help reduce the cost of P fertilization and enhance productivity with more P-efficient cultivars[10].

Alkaline soils comprise a large proportion of agricultural land throughout the world. Most of the soil in Turkey's cropping regions is calcareous and contains low amounts of plant available P, widely represented in central region and semi-arid climates[11]. Triticale is a hybrid [wheat (*Triticum* spp) × rye (*Secale cereale* L.)] and is grown in areas in which wheat is not yielded. Despite triticale being a relatively new crop in Turkey, its importance as a forage cereal crop has increased since the Turkish Ministry of Agriculture started to support triticale production. This support was supplied in the form of a direct subsidy to farmers according to the planting area[12]. The efficiency use of nutrients in wheat[1,10,13] has received considerable attention by researchers. However, there is little information on the contribution of uptake and utilization to total P use efficiency in triticale.

The present study was conducted to investigate the effect of P fertilization on grain yield and P uptake, as well as the utilization efficiency of triticale lines and varieties released in Turkey.

EXPERIMENTAL

The experiment was conducted in the experiment area of the faculty of Agriculture at Eskisehir Osmangazi University, during the year 2004-2005. Eskisehir is located in Central Anatolia in Turkey. The soil characteristics determined according to the method described by Rowell[14] were: pH 7.6 (1:1 H_2O: soil), $CaCO_3$ 70 g kg^{-1}, organic matter 5 g kg^{-1}, with a sandy loam soil texture. The concentration of $NaHCO_3$-extractable P in the soil (0-30 cm depth) was 3.4 mg kg^{-1} as measured by a method described by Olsen *et al.*[15].

The average temperature and relative humidity were 9.4 ºC and 61.3 %, respectively and total precipitation was 336.5 mm in the growing season of triticale. The field experiment was conducted with eleven triticale genotypes during 2004/2005. Six released triticale varieties (Tatlicak 97, Presto 2000, Karma 2000, Melez 2001, Mikham 2002 in Turkey and Samur sortu in Azerbaijan) and five lines (TDV-3, TVD-4, TVD-9, TVD-17 and TVD-25 from CIMMYT) were planted in October. The pedigree of triticale genotypes is given in Table-1. The experiment was set up in a completely randomized block design, with four replications and a plot size of six rows 10 m long. At planting time, nitrogen and P were applied at a standard rate of 40 kg N ha^{-1} and 26 kg P ha^{-1}. Nitrogen topdressing treatments were applied during tilling in March to a sum of 80 kg N ha^{-1}. The triticale was harvested in July by removing an area of 2 m × 3 m from the center of each plot. It was then weighed and sampled for P analysis. Grain samples were dried in a forced air oven at 60 ºC, ground to pass through a 140 mesh sieve (100 μm) and incinerated at 550 ºC in order to determine P concentration in the triticale grain and straw. The incinerated samples were dissolved in 3.3 % HCl and analyzed for P using Barton's method[16]. The concentration of grain and straw P was measured by using spectrophotometer.

TABLE-1
SOURCES OF DIFFERENT VARIETIES/LINES OF TRITICALE

No.	Line	Orgin-Pedigree
1	TVD-3	CHD 333 85/VICUNA_4 CTWS92Y2-10FM-1FM-1FM-0FM
2	TVD-4	CT1731.81/ARMINO_4 CTWS92Y6-2FM-1FM-2FM-0FM
3	TVD-9	EMS M83.6039/CT583.81//PRESTO CTWW92WM00010S-4WM-1WM-1WM-1WMR-0WM
4	TVD-17	ERIZO_10*BULL_1-1//SONNI_4-2 CTSS93B00204S-2M-0Y-0Y-0B
5	TVD-25	STIER_29/FARAS_1//2*JIL96 CTSS93B00617M-C-3Y-0M-0Y-0B-3Y-OB
	Variety	
6	Tatlicak 97	Unknown, Eucarpia
7	Presto 2000	Not available
8	Karma 2000	SWTY89.62-1 MI-OMI-OE 150-83/SHETLAND1 Pedigree SWTY89,62-1MI-0MI-0E
9	Melez 2001	GT-AD-1/91//CWT1988/79/10 BDKT910018-3F4BD-0BD
10	Mikham 2002	BDMT-19/JGS1 BDKT910036-3F4BD-0BD
11	Samur Sortu	Not available

The following parameters were calculated: Total P-uptake by grain/straw (kg/ha): P content in grain/straw (%) × total grain/biomass yield (kg); phosphorus harvest index (PHI, %): P uptake in grain (kg)/total P uptake (kg); phosphorus biological yield utilization efficiency (PBUTE): total biomass (kg)/ total P uptake (kg) and phosphorus grain yield utilization efficiency (PGUTE): grain yield (kg)/total P uptake (kg). Phosphorus utilization efficiency in biomass and grain yield was defined by Moll *et al.*[17].

11 Triticale genotypes were classified into low ($< \mu$ - 1 S), medium ($< \mu$ - 1 S to $< \mu$ + 1 S) and high ($> \mu$ + 1 S) groups based on the performance for four characters, *i.e.*, Total P uptake (kg/ha), Biological Yield (kg/ha), PHI (%), PBUTE, PGUTE and Grain Yield (kg/ha). This data is presented in Table-2. The μ and S were mean and standard deviation, respectively and were calculated according to Singh and Choudhary[18] and Gill[10].

RESULTS AND DISCUSSION

Grain yield is shown in Table-2. Grain yield ranged from 2560 (Tatlicak 97) to 3912 kg/ha (TVD-17). There were differences in grain yield for two genotypes ($p < 0.05$). In spite of no differences among varieties, grain yield differed significantly ($p < 0.05$). TVD-17 had the greatest grain yield of the lines and Karma 2000 (3325 kg/ha) had the greatest grain yield of the varieties.

Biomass yield did not differ significantly between genotypes, neither in lines nor in varieties. Presto (9500 kg/ha) had the lowest biomass of the varieties and all the genotypes, whereas TVD-4 (12366 kg/ha) had the highest biomass of both the lines and varieties, while TVD-4 had the highest grain yield (3427 kg/ha). This showed that TVD-4 produced greater straw weights (Table-2).

There was a large variation of phosphorus content in the grain yield within each group, ranging from 0.254 (Tatlicak 97) to 0.337 % (Presto 2000). There were significant differences in the P content of grain according to two cultivar groups ($p < 0.01$) (Table-2). No differences existed between the genotypic groups in relation to P content in the straw. The P content in straw was similar in Presto 2000 (0.035 %), Karma 2000 (0.034 %), Melez 2001 (0.032 %) and Samur sortu (0.031 %); however, lines had a greater P content in straw (TVD-17 and TVD-3 genotypes are 0.041 and 0.039 %, respectively).

There were significant differences in total P uptake between two genotypic groups ($p < 0.05$); however, total P uptake among lines and varieties displayed no differences (Table-2). Total P uptake ranged from 10.37 (TVD-9) to 15.62 TVD-17 in lines and 8.53 (Tatlicak 97) to 12.96 kg/ha (Karma 2000). When the mean of total P uptake between the genotypic groups was compared, it was found that lines had a greater total P uptake.

PHI indicates movement from the total P uptake of the plant to grain (Table-2). It obtained the highest value (82.84 %) for TVD-25 and the lowest (72.99 %) for Melez 2001. There were no differences between lines and varieties.

TABLE-2
MEAN VALUES OF TRITICALE GENOTYPES FOR SOME CHARACTERS AND THEIR INDEX SCORE (IN PARENTHESES)

No.	Line	Grain yield (kg/ha)	Biological yield (kg/ha)	P content in grain (%)	P content in straw (%)	Total P uptake (%)	PHI (%)	PBUTE	PGUTE	Total index score
1	TVD-3	3452(2)	11893(2)	0.289	0.039	13.27(2)	75.75(2)	933.92(2)	264.41(2)	12
2	TVD-4	3427(2)	12366(3)	0.318	0.035	14.07(2)	77.71(2)	886.09(2)	245.45(2)	13
3	TVD-9	2629(1)	12342(3)	0.296	0.026	10.34(2)	75.35(2)	1203.63(3)	255.93(2)	13
4	TVD-17	3912(3)	12005(2)	0.317	0.041	15.62(3)	79.40(2)	768.51(1)	250.39(2)	13
5	TVD-25	3517(1)	11789(2)	0.331	0.028	14.00(2)	82.84(3)	862.17(2)	251.95(2)	13
	Mean	3387	12079	0.310	0.034	13.46	78.21	930.86	253.63	–
	Variety									
6	Tatlicak 97	2560(1)	10750(2)	0.254	0.025	8.53(1)	75.97(2)	1257.51(3)	303.61(3)	12
7	Presto 2000	2983(2)	9500(1)	0.337	0.035	12.3(2)	81.61(2)	777.13(1)	242.05(2)	10
8	Karma 2000	3325(2)	11250(2)	0.315	0.034	12.96(2)	79.88(2)	867.74(2)	253.85(2)	12
9	Melez 2001	2733(2)	12250(2)	0.306	0.032	11.44(2)	72.99(1)	1087.58(2)	238.82(1)	10
10	Mikham 2002	2820(2)	10000(1)	0.322	0.027	11.03(2)	82.40(3)	904.68(2)	255.79(2)	12
11	Samur sortu	3028(2)	10250(1)	0.296	0.031	11.33(2)	79.62(2)	920.04(2)	269.30(2)	11
	Mean	2908	10667	0.305	0.031	11.27	78.75	969.11	260.57	–
	LSD ($p < 0.05$):									
	Line	783*	1974ns	0.044ns	0.015ns	4.03ns	5.71ns	234.9*	37.94ns	–
	Variety	976ns	3900ns	0.02**	0.009ns	3.32ns	8.05ns	247.53*	39.22*	–
	Combined all genotypes	829*	3221ns	0.031**	0.011ns	3.49*	7.01ns	222.9**	38.3ns	–

PBUTE was significant for both lines and varieties ($p < 0.05$) as well as for all genotypes ($p < 0.01$) (Table-2). PBUTE shows the increase of biomass yield according to total P uptake. When a comparison of all genotypes was made in terms of PBUTE, Tatlicak 97 > TVD-9 > Melez 2001 were the highest genotypes.

PGUTE was not seen to differ much among lines and all genotypes; however, it did display significant efficiency varieties (Table-2). Tatlicak 97 had the highest among all genotypes like being in PBUTE. PGUTE was slightly higher in TVD-3 compared to the lines. Tatlicak 97 has the highest potential for total P uptake conversion to grain yield of all the genotypes.

Genotypes possessing a higher grain yield under equal P conditions appeared to be the most reliable parameters for screening genotypes for total P uptake in both lines and varieties. However, this result was not true for PGUTE. Though Tatlicak 97 had the lowest grain yield (2560 kg/ha) and total P uptake (8.53 kg/ha), it also exhibited the highest PGUTE (303.61) (Fig. 1).

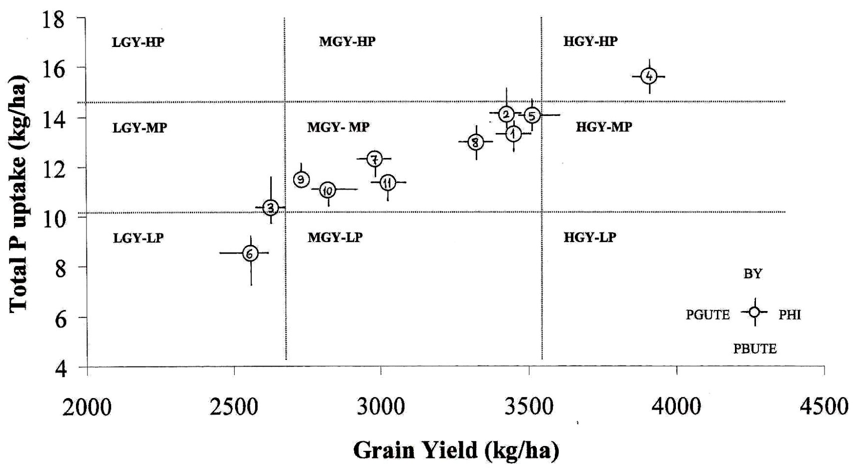

Fig. 1. Metroglyph diagram of various characters in genotypes of triticale. BY; biological yield (kg/ha), PHI; phosphorus harvest index, PBUTE; phosphorus biological yield utilization efficiency, PGUTE; phosphorus grain yield utilization efficiency. The different lines/varieties of triticale can be identified by the Nos. which are same as in Table-1

The range of variation in the triticale genotypes in relation to grain yield P uptake was examined by using Metroglyph Analysis (Fig. 1). 11 Triticale genotypes were classified into nine groups. 8 Genotypes of triticale (Melez 2001, Mikham 2002, Samur sortu, Presto 2000, TVD-4, Karma 2000, TVD-3 and TVD-25) were placed in the MGY-MP (Medium Grain Yield-Medium P uptake) group, having an index score between 10 and 13

(Table-2). Using suitable class intervals and score signs, the range of variability according to characters was classified into three groups (Table-3). No genotypes were found in the LGY-HP (low grain yield-high P uptake), MGY-LP (medium grain yield-low P uptake), MGY-HP (medium grain yield-high P uptake), HGY-MP (high grain yield-medium P uptake) and HGY-LP (high grain yield-low P uptake) groups. A genotype of triticale (TVD-17) was recorded in the HGY-HP (high grain yield-high P uptake) group. It had a higher P uptake from soil that had lowered PBUTE. The LGY-MP group had a genotype (TVD-9) which recorded an index score of 13. It had a lower grain yield score (1).

TABLE-3
CLASSIFICATION OF TRITICALE GENOTYPES ACCORDING TO SCORE OF P-UPTAKE, PHI, PBUTE, PGUTE AND GRAIN YIELD

Sign	Low (Score 1) O	Medium (Score 2) O–	High (Score 3) O—
P uptake	< 10.2 kg/ha Tatlicak 97	10.2-14.2 kg/ha TVD-3, TVD-4, TVD-9, TVD-25, Presto 2000, Karma 2000, Melez 2001, Mikham 2002, Samur sortu	> 14.2 kg/ha TVD-17
PHI	< 75.2 % Melez 2001	75.2-81.7 % TVD-3, TVD-4, TVD-9, TVD-17, Tatlicak 97, Presto 2000, Karma 2000, Samur sortu	> 81.7 % TVD-25, Mikham 2002
PBUTE	< 789.7 TVD-17	789.7-1113.7 TVD-3, TVD-4, TVD-25, Presto 2000, Karma 2000, Melez 2001, Mikham 2002, Samur sortu	> 1113.7 TVD-9, Tatlicak 97
PGUTE	< 239.6 Melez 2001	239.6-275.1 TVD-3, TVD-4, TVD-9, TVD-17, TVD-25, Presto 2000, Karma 2000, Mikham 2002, Samur sortu	> 275.1 Tatlicak 97,
Grain yield	< 2695.5 kg/ha TVD-9, Tatlicak 97	2695.5-3556.4 kg/ha TVD-3, TVD-4, TVD-25, Presto 2000, Karma 2000, Melez 2001, Mikham 2002, Samur sortu	> 3556.4 kg/ha TVD-17,
Biomass	< 10281.5 kg/ha Presto 2000, Mikham 2002, Samur sortu	10281.5-12335.7 kg/ha TVD-3, TVD-17, TVD-25, Tatlicak 97, Karma 2000, Melez 2001	> 12335.7 kg/ha TVD-4, TVD-9

The variety Tatlicak 97 had a low index score of 12, indicating the LGY-LP (low grain yield-low P uptake) group. This variety had the lowest grain yield, P content in grain, P content in straw and total P uptake.

The relationship between phosphorus content in grain and grain yield (R^2 = 0.1956) and total P uptake and biomass (R^2 = 0.1336) were positive correlated (Fig. 2). The same results were also reported by Gill[10]. In contrast, Feil and Fossati[19] and Mosali[20] observed a negative relationship. The uptake of P poses a problem for plants, since while the concentration of this mineral in the soil solution is low, plant requirements are high. The difference observed in this result may indicate that plants are greatly affected by limited P uptake due to variations in soil moisture status, root temperature and a variety of environmental factors (soil structure and climatic factors). Genotypes with inherently different growth rates or habitus (*e.g.*, tall or dwarf,

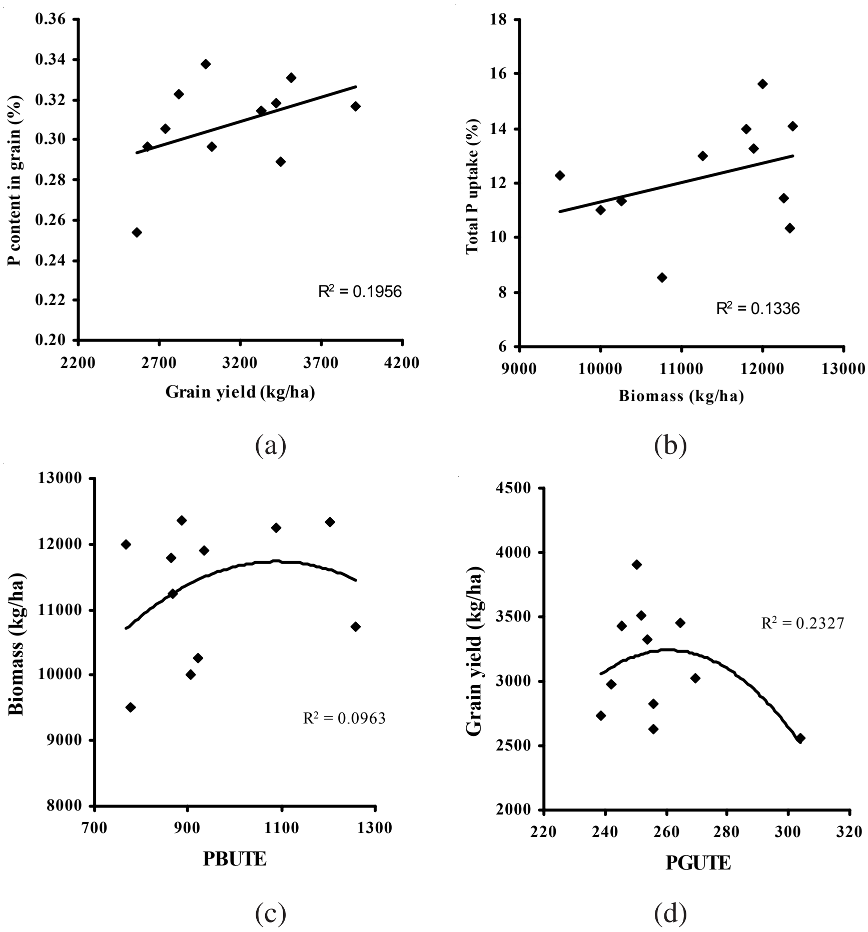

Fig. 2. Relationship between P content in grain and grain yield (a), total P uptake and biomass (b), Biomass and PBUTE (phosphorus biomass utilization efficiency) (c) grain yield and PGUTE (phosphorus grain yield utilization efficiency) (d) of 11 triticale genotypes

cultivars, slower or faster growth rate etc.) may have the same P uptake rate per biomass. However, Ozturk *et al.*[1] reported that a higher biomass production in total P uptake genotypes is achievable by enhancing P uptake by roots; thus, P taken up by the plants is used efficiently at the cellular level, contributing to better shoot growth at P supply.

Genotypes selected for use in conditions of low P supply often have a lower yield performance[21]. Yield performance for the breeder is best expressed by the input conditions[13]. Thus, the inclusion of information on both the P deficiency resistance and P use efficiency of triticale genotypes would benefit future breeding programs both economically and environmentally. Programmes aiming to further increase grain yield along with equal grain nutrient concentration should select lines with a higher capacity for nutrition uptake[22]. However, the storage form of P concentration in the seeds of small grains is phytic acid (PA), which accounts for 50 to 80 % of total grain P[23]. Some researchers have suggested[24] that PA, like Zn, Ca, Cu, Mg and Fe, acts as an anti-nutrient and that growing cultivars with low levels of PA is more advisable[25,26] as an approach to the putative health problems associated with excess PA in the diets of human and livestock.

The selection of P efficient cultivars is of the highest importance when establishing the most efficient use of phosphatic fertilizer. In order to obtain a maximum yield, while at the same time reducing the phosphatic fertilizer input, we suggest that the classification of genotypes according to P use be implemented in future breeding programmes. Gill *et al.*[10] classified 30 wheat varieties by Metroglyph analysis in relation according to their grain yield performance and P uptake. The Metroglyph analysis method is a basic way of characterizing the varied amount of genotypes available in a plant for P use responsiveness. Hence, the nine classification terms: LGY-HP, LGY-MP, LGY-LP, MGY-HP, MGY-MP, MGY-LP, HGY-HP, HGY-MP and HGY-LP. This classification allows us to confidently characterize the different genotypes in terms of both their yield performance and their P utilization efficiency under no-stressed P condition. As a result of this classification, TVD 4 is characterized as HGY-HP, indicating that this genotype is most suitable for breeding studies under calcareous soil conditions. Most triticale varieties, with the exception of Tatlicak 97, were characterized as MGY-MP. In this classification method, the variability of P efficient and inefficient utilization triticale genotypes as regards their responsiveness to the supplied P level was an important parameter in breeding studies aimed at increasing fertilizer P use efficiency and decreasing fertilizer P inputs under calcareous soil conditions.

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(*Received*: 29 October 2007; *Accepted*: 19 January 2008) AJC-6240