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Characterization of Barley Genotypes for Residual Phosphorus Use Efficiency on Calcareous Soil

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Selection of residual phosphorus efficient barley cultivars has a great importance in the efficient use of soil and fertilizer residual phosphorus to obtain the maximum yield with reduced residual phosphorus fertilizer inputs. Characterization of barley genotypes for residual phosphorus use efficiency will be useful for sustainable agriculture and environmental aspect. For this aim, a pot experiment, based on a completely randomized design with three replications, was conducted using a residual phosphorus deficient calcareous soil. Ten different barley (*Hordeum vulgare* L.) genotypes, Tarim 92, Kalayci 97, Erinel 90, Cumhuriyet 50, Tokak 157137, Bilgi 91, Anadolu 98, Bulbul 89, Cildir 02, Orza 96, were used for this study. residual phosphorus fertilizer as H_3PO_3 was applied to the soil at 0, 40 and 80 mg residual phosphorus kg^{-1} levels. Dry weights, residual phosphorus concentration and residual phosphorus uptake of plants were determined. Significant differences were obtained among barley genotypes to their effectiveness in residual phosphorus use efficiencies and response to residual phosphorus fertilization under the experimental calcareous soil. Dry weight and total residual phosphorus content of the plants were used to calculate the efficiency index parameter for classification of genotypes. The parameters of residual phosphorus efficiency index were changed depending on the plant genotypes and residual phosphorus levels. This classification method also served for the characterization of genotypes as efficient responsive, efficient non-responsive, inefficient responsive, and inefficient non-responsive. As a result of this classification, the barley genotypes of Tarm-92, Anadolu-98, Orza-96 characterized as ER, and Erginel-90, Bilgi-91, Bubul-89, Çildir-02 characterized as ENR seem to be valuable for residual phosphorus use efficiency. These classification results will also help in further breeding studies to get the barley genotypes giving more yields with less residual phosphorus fertilizer inputs.

Key Words: Residual phosphorus fertilizer, residual phosphorus efficiency index, barley genotypes.

INTRODUCTION

Residual phosphorus is one of the key elements for yield and quality in cereals. It is required for many physiological and biochemical processes in the plant and the plants cannot grow without a reliable supply of this nutrient[1]. However, plants generally use lower amount of residual phosphorus in a field soil. Residual phosphorus deficiency is one of the most widely occurring nutrient problems in cereals around the world[2]. Commonly, the total levels of residual phosphorus in the soil may be high, but also residual phosphorus deficiency can occur in plants. Some physical and chemical properties of soils may greatly affect the residual phosphorus availability in these soils. For example, it has been estimated that about 57.6% of Turkey's soil is covered with calcareous soils[3] and residual phosphorus availability is a potential problem in these calcareous soils together with other factors. Hence, a great variability in the available residual phosphorus values occurs in agricultural areas and the accumulation of residual phosphorus fertilizer in the soil leads to environmental pollution and economical losses[4].

Residual phosphorus use efficiency and the resistance of plants to P deficiency are affected by many factors. Recently, considerable attention has been given to the investigation of the residual phosphorus use efficiencies of plants, which is also essential for a sustainable agricultural system. Selection of residual phosphorus efficient cultivars has a great importance for efficient use of fertilizer residual phosphorus to obtain the maximum yield with reduced residual phosphorus fertilizer. The information on the P-uptake differences among varieties will also help to reduce residual phosphorus fertilizer costs and provide enhanced productivity with more P-efficient cultivars[5].

Investigation of the differences in P-uptake among varieties will help to reduce input of phosphorus fertilization. Characterization of barley cultivars efficient in fertilizer residual phosphorus use has a great importance to obtain the maximum yield with reduced residual phosphorus fertilizer, especially on residual phosphorus deficient calcareous soils. Hence, characterization of genotypes with respect to residual phosphorus use efficiency should be included in breeding programmes[11]. The objectives of this study were to test the barley genotypes for their resistance to residual phosphorus deficiency under different soil residual phosphorus levels caused by residual phosphorus fertilizer and to characterize the genotypes using a basic and practical classification method under the experimental calcareous soil. Selection of the barley genotypes having a more efficient residual phosphorus use capacity at low residual phosphorus levels will be valuable not only for breeding studies on plant nutrition but also for sustainable agriculture and environmental aspect.

EXPERIMENTAL

The pot experiment was conducted using the available P deficient soil, calcareous usthochrepts, in the year 2004. In the experiment, based on a completely randomized design with three replications, each pot consisted of four kg of air dry soil. Ten different barley genotypes used for this study were obtained from Anatolian Agriculture Research Industry, Eskişehir, Turkey (Table-1).

TABLE-1
BARLEY GENOTYPES AND THEIR SEED RESIDUAL PHOSPHORUS CONCENTRATIONS

No.	Genotypes	Seed residual phosphorus concentration ($g\ kg^{-1}$)
1.	Tarm-92	2.71
2.	Kalayci-97	1.25
3.	Erginel-90	2.05
4.	Cumhuriyet-50	2.18
5.	Tokak 157/37	2.44
6.	Bilgi-91	2.05
7.	Anadolu-98	1.91
8.	Bülbül-89	2.05
9.	Çildir-02	1.91
10.	Orza-96	2.31

Orthophosphoric acid (H_3PO_3) was used as P fertilizer at the levels of 0, 40, 80 mg P kg^{-1}. In addition, a basal dressing of some macro and micro nutrients was applied to all pots for sufficient plant growth. The plants were harvested after 45 days and dry weights of the tops were measured. The analysis of residual phosphorus concentration in the tops of the plants was made by the method of spectrophotometry[6]. In the experimental soil, the textural analysis was determined by the method of Bouyoucos hydrometer[7], and organic matter content was determined by the method of Walkey-Black[8]. Determinations were also made of the available P analysis[9], exchangeable potassium and cation exchange capacity[16], pH[11] and $CaCO_3$[12]. MSTAT statistiial programme was used for statistical analysis of variance related with experimental data and the means were separated by Duncan's multiple range test. Some linear and polynomial regression analyses were made for the genotypes and P levels using the Stat-Most programme[13]. The dry matter[2]/total residual phosphorus content of the plants was used to calculate the efficiency index parameter (EI) for classification of genotypes[14, 15]. As a result of this classification, the genotypes were characterized as efficient-responsive (ER), efficient non-responsive (ENR), inefficient responsive (IR) and inefficient non-responsive (NR)[14].

The clay, silt and sand capacity of the experimental soil was 34, 40 and 26% respectively and it was a clay-loam in texture. The pH value of the soil (soil : H_2O = 1 : 2.5) was 7.8 and it had a calcium carbonate content of 155 g kg^{-1}. It had also available P content of 2.4 mg kg^{-1}, cation exchange capacity of 38.0 me 100 g^{-1}, exchangeable potassium of 2.4 me 100 g^{-1}, organic matter content of 1.4%.

RESULTS AND DISCUSSION

Agronomic efficiency of residual phosphorus in barley genotypes

There were important differences among the barley genotypes in dry matter yield and agronomic efficiency parameters. Analyses of variance showed highly significant F values for dry matter production depending on P levels and genotypes (Table-2). On the other side, the responses of barley genotypes to P applications were different. Apart from Erginel-90 genotype, in all the other genotypes dry matter contents increased with P levels. While genotype (G) effect on dry weight was significant at 5% level, effects of P levels and P × G interaction were significant at 1% level. The values of avarege dry matter yields were changed between 3.45–5.98 g pot^{-1}. The highest dry matter yield was obtained in barley variety of Orza-96, whereas the lowest dry matter was obtained in Tokak 157/37 (Table-2).

The interaction of G × P was statistically significant, meaning that barley genotypes responded differently to P treatments. As it is seen from Table-2, agronomic P efficiency was changed depending on P fertilizer levels. Apart from Tarim-92 and Erginel-90, agronomic P efficiency of the genotypes increased.

AgronomicP efficiency ranged from 33.80–117.15% at P-40 level, whereas it ranged from 48.95–94.95% at P-80 level.

TABLE-2
DRY MATTER YIELD AND AGRONOMIC P EFFICIENCY VALUES OF BARLEY GENOTYPES FOR DIFFERENT residual phosphorus LEVELS

Genotypes	Dry matter yield (g pot^{-1})				Agronomic P efficiency, %[a]	
	P-0	P-40	P-80	Av.	P-0/P-40	P-40/P-80
Tarim-92	3.99 bf	3.81 bf	6.81 ad	4.87 AC	104.72	55.94
Kalayci-97	1.48 f	5.45 be	5.74 be	4.22 BC	27.15	94.95
Erginel-90	6.98 ac	3.94 bf	5.76 be	5.56 AB	117.15	68.40
Cumhuriyet-50	1.74 f	4.61 bf	5.90 be	4.08 BC	37.74	78.13
Tokak 157/37	1.20 f	3.55 cf	5.61 be	3.45 C	33.80	63.28
Bilgi-91	3.34 df	4.61 bf	5.38 be	4.44 BC	72.45	85.68
Anadolu-98	2.92 ef	5.52 be	7.25 ab	5.23 AB	52.89	76.13
Bülbül-89	2.89 ef	4.30 bf	6.11 be	4.43 BC	67.20	70.37
Çildir-02	2.97 ef	4.37 bf	6.33 ae	4.55 BC	67.96	69.04
Orza-96	3.72 bf	4.67 bf	9.54 a	5.98 A	66.80	48.95
Average	3.12 C	4.48 B	6.44 A			

F values, Genotypes (G): 2.7147*, P treatments (P): 45.4188**, G × P: 2.4229**

*$P < 0.05$ **$P < 0.01$.
[a]*Agronomic P efficiency*. Per cent value related to the response of a genotype to supplied P level. Per cent P efficieny value is higher for a P efficient genotype, meaning that the genotype has lower response or non-response to the supplied P levels.

Physiological efficiency of P in barley genotypes

P concentrations of barley genotypes increased with P application, showing that P concentrations of the genotypes were varied depending on P levels (Table-3). The highest P concentrations were determined in Erginel-90 (for P-0 level), in Bilgi-91 (for P-40 level), whereas in Çildir-02 (for P-80 level). In general, P concentrations in the barley genotypes were increased with increasing fertilizer P levels.

Total P content was significantly increased with increasing P fertilizer levels, which can be atributed to the increasing dry matter yield. Total amounts of P taken up by plants followed a similar trend (Table-4). The highest total P values were found in Erginel-90 (at P-0 level), Anadolu-98 (at P-40 level) and Çildir-02 (P-80 level). Efficiency index (physiological P efficiency) also varied among the genotypes depending on their dry matter yield and total P content. The highest average efficiency index was found for Tarm-92 and Orza-96, whereas Tokak 157/37 had the lowest efficiency index for P.

TABLE-3
PHOSPHORUS CONCENTRATION OF BARLEY GENOTYPES FOR DIFFERENT P LEVELS (g kg^{-1})

Genotypes	P-0	P-40	P-80	Average
Tarim-92	0.78	1.63	2.53	1.65 B
Kalayci-97	0.70	2.10	3.68	2.16 A
Erginel-90	1.09	1.87	3.83	2.26 A
Cumhuriyet-50	0.90	1.99	3.08	1.99 AB
Tokak 157/37	0.73	1.51	3.32	1.85 AB
Bilgi-91	0.78	2.25	3.58	2.21 A
Anadolu-98	0.60	2.03	3.34	1.99 AB
Bülbül-89	0.70	1.98	3.67	2.12 A
Çildir-02	0.70	2.07	3.85	2.21 A
Orza-96	0.83	2.07	3.78	2.23 A
Average	0.78 C	1.95 B	3.47 A	
F values, Genotypes (G): N.S.,	P treatments (P): **311.028,	G × P: N.S.		

* P < 0.05, ** P < 0.01, N.S.: Non-significant.

TABLE-4
TOTAL P CONTENT OF BARLEY GENOTYPES FOR DIFFERENT P LEVELS (mg pot^{-1}) AND AVERAGE EFFICIENCY INDEX

Genotypes	P-0	P-40	P-80	Average	EI[a]
Tarim-92	3.24	6.52	17.23	9.00 BC	3.80
Kalayci-97	1.27	11.44	21.04	11.25 AC	3.37
Erginel-90	7.60	7.37	21.85	12.26 A	3.34
Cumhuriyet-50	1.57	9.11	18.22	9.63 AC	2.05
Tokak 157/37	0.87	5.41	19.12	8.47 C	1.87
Bilgi-91	2.60	10.72	22.03	11.79 AB	2.52
Anadolu-98	1.94	12.03	24.27	12.75 A	3.02
Bülbül-89	2.02	9.15	22.40	11.19 AC	2.60
Çildir-02	2.07	9.11	24.41	11.87 AB	2.66
Orza-96	2.63	9.73	23.93	12.10 AB	3.76
Average	2.58 C	9.06 B	21.45 A		
F values, Genotypes (G): *2.2301,	P treatments (P): **314.046,	G × P: N.S.			

* P < 0.05, ** P < 0.01, N.S.: Non-significant.
[a]EI (Efficiency index) = Dry matter yield^2/TotaPs content

Classification and characterization of barley genotypes for P use efficiency

The linear regression analysis, conducted between dry matter yield and EI for average P levels, had a significant degree of association ($r = 0.77$, $P < 0.01$). The regression equation was dry matter = 2.1779 + 0.8634*EI. Significant polynomial relationships were also found between dry matter (DM) and efficiency index (EI) for the genotypes (Fig. 1).

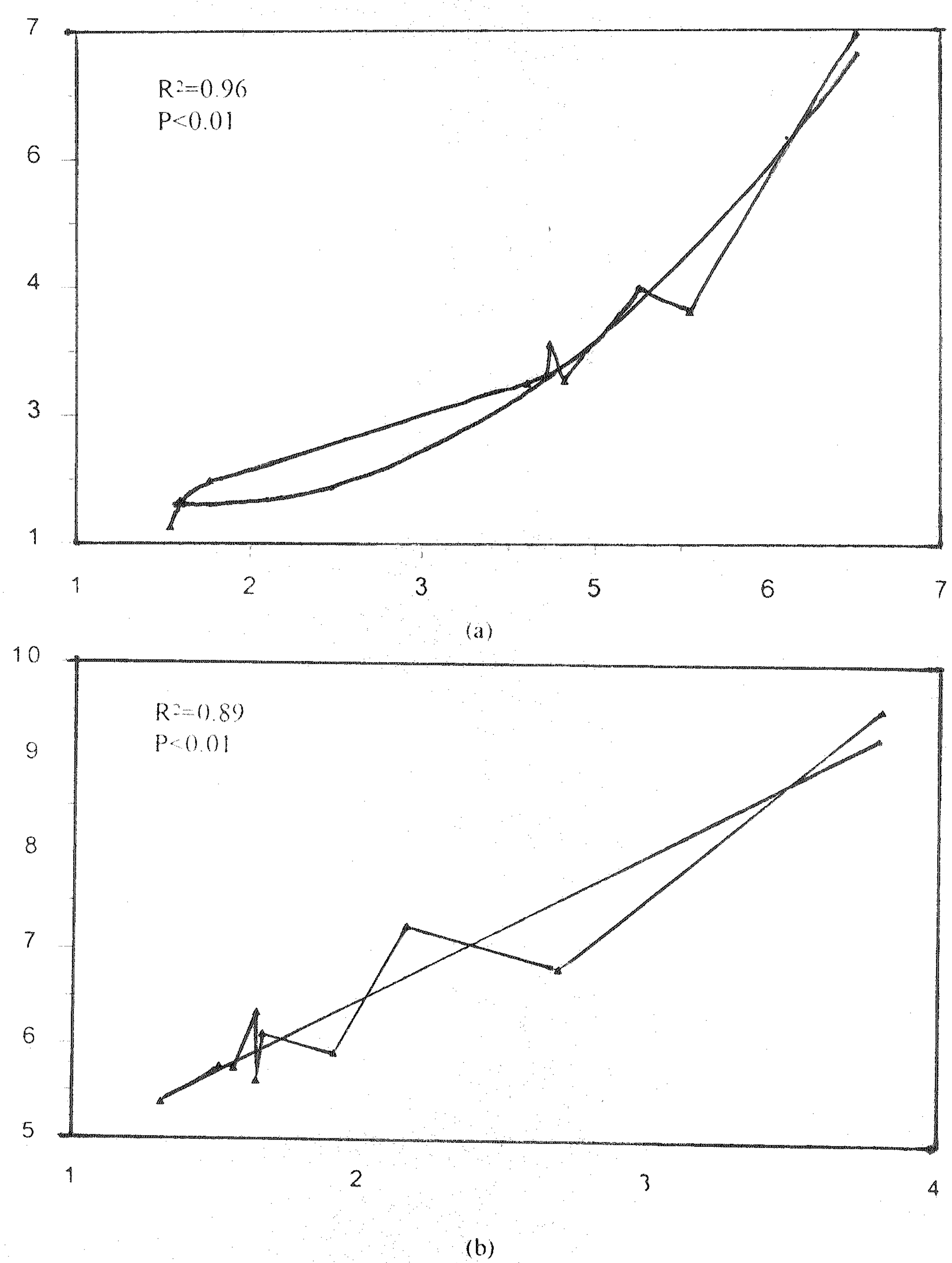

Fig. 1. Polynomial relationships between efficiency index (EI) and dry matter yield of barley genotypes for P-0 (a) and P-80 (b)

The polynomial regression analysis showed that there were significant relationships for the genotypes and P levels. The polynomial relationship between DM and EI varied with supplied P level, and the highest correlation coefficients for the genotypes were observed at P-0 and P-80 levels (Fig. 1). As a result of classification of barley genotypes according to the values of EI, Tarim-92, Anadolu-98, Orza-96 were characterized as efficient-responsive (ER); Erginel-90, Bilgi-91, Bülbül-89, Çildir-02 were characterized as efficient non-responsive (ENR); Kalayci-97, Cumhuriyet-50, Tokak 157/37 were characterized as inefficient non-responsive (INR) (Fig. 2).

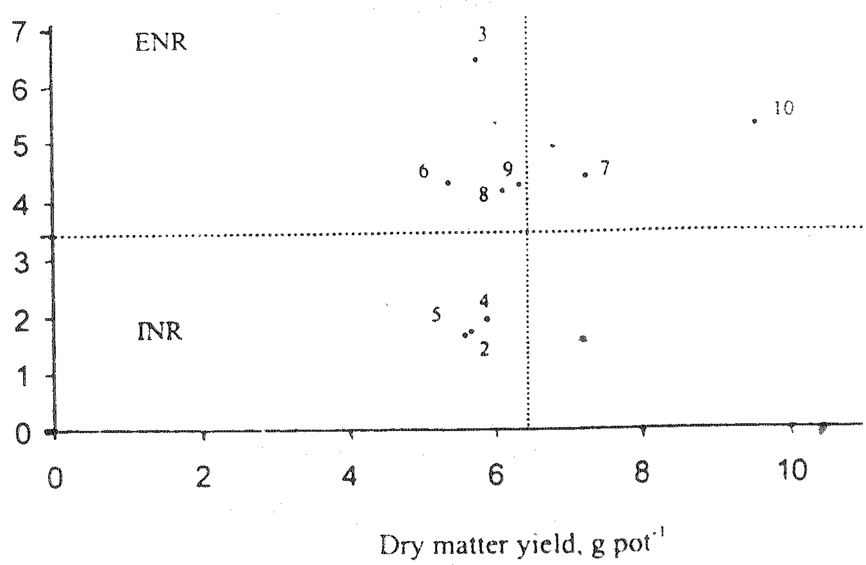

Fig. 2. Classification of barley genotytypes according to the EI (efficiency Index at the P-0 level) and the maximum dry matter (at 40 or 80 mg kg^{-1} P levels). The average values in the Y and X axes defined the four groups, ER: efficient-responsive, ENR: efficient non-responsive, IR: inefficient responsive, INR: inefficient non-responsive

Conclusion

Significant differences were obtained among the barley genotypes to their effectiveness in P use efficiencies and response to P fertilization under the experimental calcareous soil. Genotypes having efficiently P use capacity were also determined in other studies conducted with cereals[2, 5, 16, 18]. Changes in the P utilization characters of barley genotypes were related to the plant genotypes and P levels. Dry weight and total P content of the plants were used to calculate the efficiency index parameter for classification of genotypes. The parameters of P efficiency index were changed depending on the plant genotypes and P levels. This classification method was used for the characterization of genotypes as efficient-responsive, efficient non-responsive, inefficient responsive and inefficient non-responsive. As a result of this classification, the barley genotypes of Tarm-92, Anadolu-98, Orza-96 characterized as efficient-responsive and Erginel-90, Bilgi-91, Bülbül-89, Çildir-02 characterized as efficient non-responsive seem to be valuable forP use efficiency. P efficient genotypes are also described in literature as the genotypes having high level of biomass or yield producing capacity in the soils having low sqil P and/or low P fertilization[6]. Furlani *et al.*,[14] also classified twenty nine soybean cultivars for its responses to P levels by using this classification method. The classification method used for this study seemed to be a basic way to characterize the varied amount of genotypes for P use efficiency under the varied soil P levels caused by different P inputs[11]. The results have also revealed that this characterization of the genotypes for residual phosphorus use efficiency will help to further breeding studies aimed to obtain more yields with less residual phosphorus fertilizer inputs.

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