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Characterization of Some Barley Cultivars (*H. Vulgare* spp.) for their Response to Iron Deficiency on Calcareous Soil

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The iron efficiency and responsive barley genotypes will provide valuable genetic resource for sustaining the optimal yields and quality of barley cultivars. This characterization for developed genotypes under the varied soil conditions will be useful for sustainable agriculture and environmental aspect. For this aim, a pot experiment, based on a completely randomised design with three replications, was conducted using calcareous soil. 20 Barley varieties of Tarm-93, Kearney, Orza, Kaya, Morex, Herrington, Ince-2004, Rihane, Baronesse, Golden Promise, Avustralya, Steptoe, Yesevi-93, Schuyler, NE-93760, Bulbul, Barke, Dicktoo, Ozdemir-2005 and Yerçil-147 were used for this study. Ferrous sulphate monohydrate as iron fertilizer at the levels of 0 and 10 mg Fe kg^{-1} were applied to the pots. After harvest, dry matter yield, tillering number and length of the plants were recorded. Total P, Fe, Cu, Zn and Mn concentrations in tops of barlyes were also determined. Dry weight (DM) and total iron content of the plants were used to calculate the efficiency index parameter for classification of genotypes. The parameter of iron efficiency index (EI) was changed depending on the plant genotypes and iron levels. This classification method also served for the characterization of genotypes as ER (efficient-responsive), ENR (efficient non-responsive), IR (inefficient responsive) and INR (inefficient non- responsive). As a result of this classification, the barley genotypes of Avustralya, Yesevi-93, Steptoe, Ince-2004, Baronesse, Herrington, Yerçil-147 were characterized as ER, whereas Bulbul and Ozdemir-2005 was characterized as ENR seems to be valuable for iron efficiency.

Key Words: Barley, Genotypic variation, Iron deficiency.

INTRODUCTION

Total levels of iron in the soil may be high, but sometimes iron deficiency can occur in plants. Some physical and chemical properties of soils may greatly affect the iron availability on these soils[1]. Many iron fertilizers were developed for controlling of iron chlorosis, but their high costs generally restrict widely use of these iron sources in the agricultural crops[2-4]. Thus, economical benefits will be obtained by increasing of iron use efficiency and resistance to iron deficiency of agricultural crops[5]. On the other hand, iron use efficiencies of the plants are affected by many factors[6]. Hence, many studies revealed that there were broad differences among plant species and genotypes associated with susceptibility to iron deficiency due to the different strategies of these varieties[7,8].

In recent years, sustainable agriculture has been an important alternative to sustain agricultural production by using local sources of nutrients with reduced environmental pollution. Selection of iron efficient barley cultivars has a great importance for efficient use of soil and fertilizer iron to obtain the maximum yield and quality. Characterization of barley genotypes for iron use efficiency will be useful for sustainable agriculture and environmental aspect. It is generally known that plant species or genotypes affects the iron availability and uptakes by plants, whereas additional studies would be needed concerning these relationships. The objectives of this study is to test the barley genotypes for their resistance to iron deficiency under different soil, iron levels caused by iron fertiliser and to characterize the genotypes using a basic and practical classification method under the experimental calcareous soil.

EXPERIMENTAL

A pot experiment was conducted using the available iron deficient soil, calcareous usthochrepts, in the year of 2005. In the experiment, based on a completely randomised design with three replications, each pot consisted of 4 kg of air dry soil. Barley genotypes, Tarm-93, Kearney, Orza, Kaya, Morex, Herrington, Ince-2004, Rihane, Baronesse, Golden Promise, Avustralya, Steptoe, Yesevi-93, Schuyler, NE-93760, Bulbul, Barke, Dicktoo, Ozdemir-2005, Yerçil-147, were used for this study. Ferrous sulphate monohydrate was used as iron fertilizer at the levels of 0 and 10 mg Fe kg^{-1}. For normal growth, nitrogen fertilizer at the rate of 150 mg N kg^{-1} as ammonium sulphate and phosphorus at the rate of 100 mg P kg^{-1} as KH_2PO_4 were applied to all pots. In addition, a basal dressing of some macro and micro nutrients were applied to all pots for normal plant growth. The plants were harvested after 49 d and dry matter yield, tillering number and plant length were recorded. The analyses for Fe, Cu, Zn and Mn concentrations of plant samples were made by ICP spectrometry[9]. In the experimental soil, DTPA-extractable Fe, Cu, Zn, Mn were determined by the method of Lindsay and Norvell[10]. The textural analysis was made by the method of Bouyoucos hydrometer[11] and organic matter content was made by the method of *Walkey-Black, (1947)*. Determinations were also made for available P[12], exchangeable potassium[13], cation exchange capacity, pH[14] and $CaCO_3$[15]. Dry weight (dm) and total iron content of the plants were also used to calculate the Efficiency Index Parameter (dm^2/ total Fe content) for classification of genotypes. As a result of classification of barley genotypes according to EI (Efficiency Index at Fe-0 level) and maximum dry matter yield (at Fe-10 level), the average values in the Y and X axis defined the four groups; ER: efficient-responsive, ENR: efficient non-responsive, IR: inefficient responsive, INR: inefficient non-responsive[16,17]. Coefficients of variance concerned with some relationships were also calculated using the computer program StatMost[18].

The experimental soil was clay-loam in texture. The pH value was 8.66 and had a calcium carbonate content of 261 g kg^{-1}. Organic matter content was 0.57 %. It had also available P content of 3.4 mg kg^{-1}, cation exchange capacity of 37.77 me 100 g^{-1}, available K content of 200 mg kg^{-1}, DTPA extractable Fe, Zn, Cu and Mn contens of 3.2, 0.20 and 1.7 μg g^{-1}, respectively.

RESULTS AND DISCUSSION

Plant length, tillering number and dry matter yield of barley genotypes: Analyses of variance showed highly significant F values for plant length, tillering number and dry matter yield of barleys depending on iron levels and genotypes. Average tillering number values ranged from 14.67 to 47.67 at Fe-0 level, whereas it ranged from 15.00 to 42.67 at Fe-10 level. The highest value for plant length was obtained in Yesevi-93, whereas the lowest value was obtained in NE-93760 at Fe-0 level (Table-1). Dry matter yield was significantly increased with increasing iron fertilizer levels (Table-2). Barley genotypes responded differently to iron treatments. Dry matter yields ranged from 3.84 to 7.79 g pot^{-1} at Fe-0 level, whereas it ranged from 4.11 to 7.31 g pot^{-1} at Fe-10 level. The highest dry matter yield was obtained in barley varieties of Herrington and Yerçil-147, whereas the lowest dry matter was obtained in Morex. The values of agronomic Fe efficiency were differed among the barley genotypes. Agronomic Fe efficiency of barley genotypes ranged from 79.28 to 109.54 % at Fe-10 level. The varieties of Yerçil-147, Schuyler, Yesevi-93, Baronesse and Herrington had the highest agronomic iron efficiency, whereas Orza and Golden Promise varieties had the lowest agronomic iron efficiency (Table-2).

Physiological efficiency of iron in barley genotypes: The iron concentrations of the barley genotypes were clearly influenced depending on iron levels and barley genotypes (Table-3). Changes in the iron utilization characters of barley genotypes were related to the genotypes and iron levels. The highest iron concentration was obtained in Yesevi-93 at Fe-0

TABLE-1
AVERAGE VALUES FOR TILLERING NUMBER AND PLANT LENGTH OF BARLEY GENOTYPES UNDER DIFFERENT IRON LEVELS

Barley Genotypes	Tillering number			Plant length (cm)		
	-Fe	+Fe	Average	-Fe	+Fe	Average
Tarm-93	30.67	32.67	31.67be	29.67ae	30.50ad	30.08ac
Kearney	47.67	51.00	49.33a	17.83lm	18.67kl	18.25ı
Orza	25.33	28.33	26.83cf	27.33eı	31.83a	29.58bd
Kaya	27.67	31.00	29.33cf	28.83bf	30.33ad	29.58bd
Morex	16.67	15.00	15.83g	20.67jk	25.67hı	23.17g
Herrington	33.00	37.00	35.00bd	29.00bf	25.50hı	27.25ef
Ince-2004	24.00	30.33	27.17cf	30.83ac	30.67ac	30.75ab
Rihane	22.33	21.33	21.83fg	28.67cf	27.50eı	28.08df
Baronesse	34.67	32.00	33.33be	28.67cf	28.50cg	28.58ce
G. promise	28.67	34.33	31.50ce	19.00kl	22.33j	20.67h
Avustralya	24.67	26.67	25.67df	25.33ı	28.00dh	26.67ce
Steptoe	15.67	15.67	15.67g	26.83fı	30.50ad	28.67ce
Yesevi-93	24.67	26.67	25.67df	31.83a	31.33ab	31.58a
Schuyler	37.67	33.33	35.50be	18.00lm	18.83kl	18.42ı
NE-93760	39.33	42.67	41.00ab	12.17o	15.50mn	13.83j
Bulbul	30.00	19.33	25.67df	28.67cf	31.33ab	30.00ac
Barke	22.00	26.33	24.17eg	31.33ab	30.17ad	30.75ab
Dicktoo	32.33	34.67	33.50be	14.17no	15.00n	14.58j
Ozdemir-2005	14.67	16.67	15.67g	26.00gı	31.67a	28.83ce
Yerçil-147	27.00	26.33	26.67cf	30.50ad	29.67ae	30.08ac
Average	27.93	29.07	28.50	25.27a	26.68a	25.97

F test for tillering: Genotypes (G): 11.7355**, Fe levels (Fe): N.S., G × Fe: N.S.
F test for length: Genotypes (G): 136.1938**, Fe levels (Fe): 43.4718**, G × Fe: 6.2658**, *; $p < 0.05$, **; $p < 0.01$, N.S.: Non-significant

level, whereas it was obtained in Kaya, Morex, Schuyler and Barke varieties at Fe-10 level. Total iron content was significantly increased with increasing iron levels. In Fe-10 level, the varieties of Dicktoo and Herrington had the highest total iron content. However, the varieties of NE-93760 and Herrington had the highest total iron content for Fe-0 level. Efficiency index values of iron (physiological iron efficiency) were also varied among the genotypes depending on their dry matter yield and total iron content. The highest avarege efficiency index values were obtained for Yerçil-147, Yesevi-93, Ozdemir-2005 and Avustralya, whereas the lowest values were obtained for NE-93760, Morex and Dicktoo (Table-3).

TABLE-2
DRY MATTER YIELD AND AGRONOMIC IRON EFFICIENCY PARAMETERS FOR BARLEY GENOTYPES UNDER DIFFERENT IRON LEVELS

Barley Genotypes	Dry matter yield, (g pot^{-1})			Agronomic Fe Efficiency (%)[a]
	-Fe	+Fe	Av.	Fe-0/Fe-10
Tarm-93	6.38	7.00	6.69ac	91.14
Kearney	4.79	5.14	4.97cd	93.19
Orza	5.37	6.90	6.14ac	77.82
Kaya	5.41	5.56	5.49bd	97.30
Morex	3.84	4.11	3.98d	93.43
Herrington	7.73	7.31	7.52a	105.74
Ince-2004	6.60	7.05	6.82ac	93.61
Rihane	5.05	5.84	5.45bd	86.47
Baronesse	7.25	6.81	7.03ab	106.46
Golden promise	5.09	6.42	5.76ad	79.28
Avustralya	6.02	6.88	6.45ac	87.50
Steptoe	6.33	7.01	6.67ac	90.29
Yesevi-93	6.93	6.40	6.66ac	108.28
Schuyler	5.51	5.03	5.27bd	109.54
NE-93760	4.39	5.41	4.90cd	81.14
Bulbul	6.08	6.17	6.13ac	98.54
Barke	6.76	6.80	6.78ac	99.41
Dicktoo	4.65	5.69	5.17bd	81.72
Ozdemir-2005	5.78	6.29	6.03ac	91.89
Yerçil-147	7.79	7.31	7.55a	106.56
Average	5.89	6.26	6.07	

F test: Genotypes (G): 3.1238**, Fe levels (Fe): N.S., G x Fe: N.S.
*; P < 0.05, **; P < 0.01, N.S.: Non significant
[a]Agronomic iron efficiency = Per cent value related to the response of a genotype to supplied iron level. In iron efficient genotype, per cent iron efficiency value is higher, which means that the genotype has lower response or non-response to the supplied iron levels.

Classification and characterization of barley genotypes for iron use efficiency: The lineer regression analysis, conducted between average dry matter yield and EI (Efficiency Index) values for avarege iron levels, had a significant degree of association ($r = 0.70$ and $p < 0.01$). The regression equation was $DM = 3.2556 + 0.0394 * EI$. As a result of classification of barley genotypes according to the values of EI, the varieties of Avustralya, Yesevi-93, Steptoe, Ince-2004, Baronesse, Herrington, Yerçil-147 were characterized as ER (efficient-responsive); Bulbul and Ozdemir-2005 were characterized as ENR (efficient non-responsive); Morex, Kearney, Schuyler, Dicktoo, Kaya, Rihane, Golden Promise, NE-93760 were characterized as INR (inefficient non-responsive); Barke, Tarm-93 and Orza were characterized as IR (inefficient responsive).

TABLE-3
IRON CONCENTRATIONS AND TOTAL IRON CONTENT OF BARLEY GENOTYPES UNDER DIFFERENT IRON LEVELS AND EI VALUES

Barley Genotypes	Fe concentration ($\mu g\ g^{-1}$)			Total Fe content ($\mu g\ pot^{-1}$)			Efficiency Index
	-Fe	+Fe	Av.	-Fe	+Fe	Av.	EI[a]x1000
Tarm-93	89.70	98.20	93.95bc	593.72	650.84	622.3ac	71.8
Kearney	94.50	85.17	89.83bc	428.85	498.13	463.5cd	53.3
Orza	75.83	85.40	80.62bc	529.16	589.08	559.1bd	67.6
Kaya	84.30	120.27	102.28bc	416.68	474.96	445.8cd	67.6
Morex	82.60	112.27	97.43bc	313.74	520.02	416.9cd	39.6
Herrington	69.07	80.07	74.57bc	638.72	817.59	728.2ab	79.4
Ince-2004	79.70	85.83	82.77bc	454.79	566.06	510.4cd	91.7
Rihane	77.97	98.73	88.35bc	405.41	504.13	454.8cd	65.3
Baronesse	78.90	93.20	86.05bc	569.42	668.32	618.9ac	80.8
G. promise	62.27	91.13	76.70bc	377.30	594.02	485.7cd	68.9
Avustralya	69.17	94.77	81.97bc	376.51	623.50	500.0cd	86.1
Steptoe	68.93	73.43	71.18bc	428.83	661.26	545.1bd	84.0
Yesevi-93	105.07	100.47	102.77bc	480.61	475.58	478.1cd	93.1
Schuyler	249.10	112.23	180.67a	576.52	515.49	546.0bd	50.9
NE-93760	64.40	93.60	79.00bc	985.11	611.76	798.4a	33.7
Bulbul	75.93	81.40	78.67bc	391.54	561.64	476.6cd	81.1
Barke	96.73	127.17	111.95b	514.28	553.66	534.0bd	86.3
Dicktoo	60.63	63.63	62.13c	447.99	721.26	584.6bc	46.6
Ozdemir-2005	66.47	82.03	74.25bc	336.73	398.67	367.7d	94.4
Yerçil-147	87.22	93.56	90.39bc	517.96	598.80	558.0bd	103.3
Average	89.70b	98.20a	93.95	489.20b	580.20a		

F test for Fe concentration : Genotypes (G): 2.2514**, Fe treatments (Fe): N.S., G x Fe : N.S.; F test for Fe content : Genotypes (G): 1.9357*, Fe treatments (Fe): N.S., G x Fe : N.S.

[a] Efficiency Index (EI) (x 1000) = dry matter yield^2 / total Fe content, and it provides to select barley genotypes with improved Fe utilization characters as ER (efficient-responsive), ENR (efficient non-responsive), IR (inefficient responsive) and INR (inefficient non-responsive).

P, Cu, Zn and Mn status of barley genotypes under different iron levels: As it is seen from Table-4, phosphorus uptake by barley genotypes was changed depending on genotypes. The highest phosphorus content was obtained in Yerçil-147, whereas the lowest value was obtained in Morex. Effect of iron levels on copper and manganese concentrations and contents of the genotypes were not significant, whereas it was differed among the genotypes. Zinc concentration of the plants decreased with increasing iron levels. Zinc concentrations were also varied among the genotypes. The highest zinc concentration was obtained in Herrington, whereas the lowest value was obtained in Bulbul (Table-4).

TABLE-4
AVERAGE P, Cu, Zn and Mn CONCENTRATIONS AND CONTENTS OF BARLEY GENOTYPES UNDER DIFFERENT IRON LEVELS

Barley Genotypes	P		Cu		Zn		Mn	
	g kg^{-1}	mg pot^{-1}	µg g^{-1}	µg pot^{-1}	µg g^{-1}	µg pot^{-1}	µg g^{-1}	µg pot^{-1}
Tarm-93	2.90dg	19.83bd	8.10gh	54.11dh	17.21cd	114.26	46.92fh	313.52ce
Kearney	3.90ab	19.38bd	12.97ac	64.86bf	18.68cd	92.93	50.61ch	251.93de
Orza	2.80dg	17.10ce	9.09fg	55.71dh	14.74cd	91.54	53.73cg	328.32ce
Kaya	3.30be	18.11cd	12.59ac	68.22bd	17.46cd	94.04	57.57ce	312.89ce
Morex	2.40g	9.53e	11.50cd	45.92fh	22.12cd	86.73	59.34cd	234.39e
Herrington	3.50bd	25.99ab	13.70a	102.70a	68.86a	516.15	52.77ch	395.71ac
Ince2004	3.00cg	20.39ad	11.67bd	79.28bc	21.78cd	149.90	49.95dh	340.01be
Rihane	2.90dg	15.87de	9.06fg	49.46dh	17.47cd	95.07	48.39eh	265.53de
Baronesse	3.50be	24.28ac	11.64bd	81.51ab	17.38cd	122.59	49.80dh	348.73bd
G. Promise	3.30be	19.00bd	13.73a	78.21bc	23.06cd	124.92	82.02b	468.30a
Avustralya	2.80dg	18.25cd	9.81ef	63.89bg	15.18cd	98.66	55.31cf	359.45ad
Steptoe	2.50fg	15.91de	9.06fg	59.80ch	34.18b	208.08	45.14gh	296.85ce
Yesevi-93	2.80dg	19.02bd	6.91hı	46.36eh	32.44b	216.28	45.35fh	303.30ce
Schuyler	3.30be	17.64cd	12.82ac	67.26bf	23.44c	127.03	76.10b	398.08ac
NE-93760	3.10fc	15.91de	12.84ac	62.91bg	18.67cd	88.38	92.93a	443.44ab
Bulbul	3.10cg	18.68bd	7.04hı	42.91gh	14.27d	87.18	51.01ch	311.47ce
Barke	3.30be	22.42ad	10.40df	70.18bd	17.26cd	117.35	60.18c	405.76ac
Dicktoo	4.60a	23.67ac	13.08ab	67.51be	20.88cd	107.02	77.12b	396.44ac
Ozdemir-05	2.80eg	16.77ce	6.53ı	39.03h	14.99cd	93.83	43.09h	256.81de
Yerçil-147	3.70bc	27.75a	10.60de	79.97bc	18.41cd	138.58	53.24cg	401.17ac
LSD values	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Fe levels								
-Fe	3.10	18.35	10.66	61.86	24.46	147.87	57.61	328.49
+Fe	3.20	20.20	10.66	66.12	20.39	129.18	57.44	354.72
LSD values	0.069**	7.636**	1.472**	21.40**	8.848**	12.04**	9.981**	25.07*

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

Conclusion

The performance of a specific barley variety for iron use efficiency was not the similar under the iron deficient and non deficient conditions. Significant differences were obtained among the barley genotypes to their effectiveness in Fe use efficiencies and responses to Fe fertilization under the experimental calcareous soil. Plant genotype differences to take up iron from the soil were also determined in other studies[5,19,20]. The classification method used for this study is a basic way to characterize the varied amount of genotypes for both phosphorus efficiency and phosphorus use responsive under the varied soil conditions[17,21,22]. In this study, this classification method was used for the characterization of genotypes as ER (efficient-responsive), ENR (efficient non-responsive), IR (inefficient responsive) and INR (inefficient non-responsive) for iron efficiency and iron use. As a result of this classification, the barley genotypes of Avustralya, Yesevi-93, Steptoe, Ince-2004, Baronesse, Herrington, Yerçil-147 were characterized as ER (efficient-responsive); *Bulbul and Ozdemir-2005* were characterized as ENR (efficient non-responsive) seems to be valuable for Fe use efficiency. Selection of the barley genotypes having more efficient Fe use capacity will be valuable not only for breeding studies on plant nutrition but also for sustainable agriculture and environmental aspect.

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