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Selection of bacterium (*Rhizobium* Spp.) inoculated chickpea genotypes for residual P use effect on following wheat plants

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Abstract

Selection of phosphorus (P) efficient cultivars has a great importance for sustainable soil fertility to obtain the maximum yield with reduced environmental pollution. Determination of subsequent effect of P efficient genotypes on following crops may also provide valuable genetic resources for sustaining organic production. For this aim, a pot experiment, based on a completely randomized design with three replications, was conducted using a calcareous soil. Twelve different chickpea genotypes, Aydın-92, Meksika, Diyar-95, Sarı-98, Er-99, Aziziye-94, Cevdet-98, Gökçe, ILC-1482, İzmir-92, Çağatay, Konya, Gülümser, Akçin-91, Yerlisıra, Menemen-92, Küsmen-99, Eser-87, Uzunlu-99 and Damla-89 were used under the bacterium-inoculated and non-inoculated conditions. Phosphorus fertilizer at the levels of 0 (control) and 80 mg $P \cdot kg^{-1}$ was applied to the pots. After harvesting of chickpea genotypes, wheat variety of Ziyabey-98 was planted to the same pots to determine the subsequent effect of bacterium-inoculated chickpea genotypes on P use efficiency of following plants. As a result of the experiment, top dry matter yields of wheat plants were recorded. The highest dry matter yield of 4.42 $g \cdot pot^{-1}$ was obtained from followed chickpea variety of Izmir-92. The lowest yields were obtained from followed chickpea varieties of Gülümser (1.68 $g \cdot pot^{-1}$), Eser-87 (1.60 $g \cdot pot^{-1}$) and Küsmen-99 (1.35 $g \cdot pot^{-1}$). Significant differences were obtained for P use efficiencies of wheat plants depending on residual effect of bacterium inoculated chickpea genotypes under the experimental conditions. Genotype x bacterium inoculation interaction was also statistically significant. The results have also revealed that selection of chickpea genotypes for residual P use effect on the following wheat plants will have a valuable contribution for breeding studies. Conducting similar studies with other crop species will be useful for sustainable organic agriculture.

Keywords : Chickpea genotypes, *Rhizobium* bacterium, wheat plant, phosphorus

Introduction

Recently, sustainable agriculture has been an important alternative to sustain agricultural production by using natural resources effectively. For this aspect, efficient use of inorganic fertilizer will contribute to the sustainability of natural resources. For example, large amount of the applied fertilizer P remains in soils as residues. This may result in considerable phosphorus accumulation in the soil. Depending on geochemical attributes, soils may immobilize fertilizer phosphorus. On such soils, the efficiency of fertilizer phosphorus can be low, with only 10 to 30 % of the P applied available for plant uptake in the year of application (McLaughlin et al., 1988; Wakelin and Ryder, 2004). Thus, the accumulation of P fertilizer in the soil is a serious problem for environmental pollution and economical losses.

Soil and climatic conditions together with farmer management can affect the availability of the P in the fields. It has been reported that various plant species developed physiological or morphological mechanisms to improve nutrient use efficiency under infertile soils (Romheld, 1998). Thus, nutrient concentration and uptake by different plant genotypes are the most important criteria for diagnosing the existing genetic specificity of plant nutrition (Saric, 1987). Genotypes having efficient P use capacity were determined in other studies conducted with cereals (Graham, 1984; Karaman and Şahin, 2004; Karaman et al., 2005). Phosphorus use efficiency and the resistance of plants to P deficiency are affected by many factors. Different adaptation mechanisms to low P conditions exist. Organic acid secretion of plants to rhizosphere has a very important role in adaptation of plants to P deficiency conditions. For example, proteoid roots of white lupin secrete citric acid (Gardner et al., 1983). Phosphorus efficient genotypes are also described in literatures as the genotypes with high level of biomass or yield producing capacity in the soils with low soil P and/or low P fertilization (Gabelman and Gerloff, 1983).

On the other hand, it has been reported that nodulated legumes require high levels of P for optimal symbiotic performance (Deng et al., 1998). It has also been emphasized that plants obtaining N from symbiosis require higher levels of P for optimal growth than other plants obtaining N from nitrogen fertilizers (Israel, 1987). Thus, N source is a very important criterion for the amount of P required, and there is a closely relationship between P level and symbiotic mechanism in legumes (Itoh, 1987; Pereira and Bliss, 1987). Hence, selection of P efficient legume cultivars has a great importance for efficient use of fertilizer P to obtain the maximum yield and quality. Determination of effect of P efficient genotypes on the subsequent crop may also provide considerable genetic resources for sustaining the following yields and quality with reduced P supply. It will be valuable not only for breeding studies on plant nutrition but also for sustainable agriculture and environmental aspect.

Materials and Methods

A pot experiment, based on a completely randomized design with three replications, was conducted using a calcareous soil. Twelve different chickpea genotypes were used under the bacterium inoculated and non-inoculated conditions. The genotypes used were Aydın-92 (T), Meksika (S), Diyar-95 (unknown), Sarı-98 (T), Er-99 (R), Aziziye-94 (R), Cevdet-98 (T), Gökçe (R), ILC-1482 (R), İzmir-92 (T), Çağatay (T), Konya (S), Gülümser (T), Akçin-91 (T), Yerli sıra (S), Menemen-92 (T), Küsmen-99 (R), Eser-87 (T), Uzunlu-99 (T) and Damla-89 (T), with the letters in parenthesis indicating resistance to blight as T (Tolerance), R (Resistance) and S (Susceptible). Phosphorus fertilizer as H_3PO_3 at the levels of 0 and 80 mg $P{\cdot}kg^{-1}$ was applied to the pots. Nitrogenous fertilizer at the level of 60 mg $N{\cdot}kg^{-1}$ as ammonium nitrate was applied to all pots for normal growth. After harvesting of chickpea genotypes, Ziyabey 98 wheat variety was planted to the same pots to determine the subsequent effect of bacterium inoculated chickpea genotypes on P use efficiency of following plants. As a result of the experiment, plant dry matter yields of wheat plants were recorded. Total P concentrations in aerial parts of the plants were also determined. The analysis for P concentration in the plants was made by spectrophotometry after digestion (Barton, 1948).

In the experimental soil, available P analysis was made through the method of Olsen et al., 1954. Also, the textural analysis with a Bouyoucos hydrometer (Gee & Bouder, 1986), organic matter content with the Walkley-Black method (Jackson, 1956), exchangable potassium and C.E.C. (Richards, 1954), $CaCO_3$ (Chapman & Pratt, 1961) and pH (McLean, 1986) values were determined. Experimental data were subjected to statistical analysis and the means were separated by Duncan's multiple range test. The calcareous soil used in this study was clay-loam in texture with 36, 34 and 30 percent clay, silt and sand, respectively, and the calcium carbonate content was 159 $g{\cdot}kg^{-1}$. It had also the following chemical properties: pH (7.84), organic matter content (1.7%), available phosphorus (7.03 mg $P{\cdot}kg^{-1}$), exchangeable potassium (6.4 me·100 g^{-1}) and cation exchange capacity (35.2 me·100 g^{-1}).

Results and Discussion

Residual effect of bacterium inoculated chickpea genotypes on dry matter yield of following wheat at different P levels is presented in Table 1. The analysis of variance showed statistically highly significant differences for dry matter production among the genotypes at different P levels.

Table 1: Residual effect of bacterium inoculated chickpea genotypes on dry matter yield of following wheat at different P levels ($g{\cdot}pot^{-1}$)

Genotypes	Non-inoculated			Inoculated			Average
	P-0	P-80	Average	P-0	P-80	Av.	
Aydın-92	2.53	2.66	2.61 af	4.11	3.78	3.94 ad	3.27 AE
Meksika	4.38	4.45	4.41 ac	1.95	4.58	3.26 af	3.84 AD
Diyar-95	1.75	4.18	2.96 af	2.18	2.55	2.36 af	2.66 DF
Sarı-98	1.41	3.31	2.36 af	1.38	4.38	2.88 af	2.62 DF
Er-99	1.55	4.38	2.96 af	2.10	3.30	2.70 af	2.83 BF
Aziziye-94	1.15	4.18	2.66 af	1.35	3.12	2.23 bf	2.45 DF
Cevdet-98	1.71	4.11	2.91 af	1.28	3.33	2.30 af	2.61 DF
Gökçe	1.41	3.85	2.63 af	1.15	4.85	3.00 af	2.81 BF
ILC-1482	1.41	5.40	3.40 af	1.88	7.81	4.85 a	4.12 AC
İzmir-92	4.21	4.71	4.46 ac	2.95	5.80	4.37 ac	4.42 A
Çağatay	1.03	3.28	2.15 bf	0.81	2.18	1.56 df	1.82 EF
Konya	1.95	3.71	2.83 af	1.20	3.48	2.34 af	2.58 DF
Gülümser	1.43	2.99	2.21 bf	1.05	1.26	1.16 ef	1.68 F
Akçin-91	2.08	2.01	2.05 bf	0.68	3.11	1.90 cf	1.97 EF
Y. Sıra	0.96	2.88	1.92 cf	1.63	3.45	2.54 af	2.23 EF
Menemen-92	0.68	1.99	1.33 ef	2.31	3.21	2.76 af	2.05 EF
Küsmen-99	1.05	1.18	1.11 f	0.63	2.55	1.59 df	1.35 F
Eser-87	1.12	1.83	1.47 df	1.11	2.36	1.74 df	1.60 F
Uzunlu-99	1.05	6.38	3.71 ae	1.55	7.68	4.61 af	4.16 AB
Damla-89	1.61	4.35	2.98 af	1.48	3.38	2.43 af	2.70 CF
Average	1.65 b	3.59 a	2.66	1.63 b	3.81 a	2.72	

* Means with the same letter in the same column are not significant at 1 % level.

Dry matter yield of wheat varied from 1.35 and 4.42 g·pot^{-1}. The highest dry matter yield of 4.42 g·pot^{-1} was obtained from followed chickpea variety of Izmir-92. The lowest yields were obtained from followed chickpea varieties of Gülümser (1.68 g·pot^{-1}), Eser-87 (1.60 g·pot^{-1}) and Küsmen-99 (1.35 g·pot^{-1}). Although not statistically significant, dry matter yields were higher in bacterium inoculation (2.77 g·pot^{-1}) than non-inoculation (2.66 g·pot^{-1}). Considering the P application, P80 level resulted in higher dry matter yields both in non-inoculated (3.59 g·pot^{-1}) and inoculated (3.81 g·pot^{-1}) conditions than P0 treatment (1.65, 1.63 g·pot^{-1}), respectively.

Significant differences were obtained for P use efficiencies of wheat plants depending on residual effect of bacterium inoculated chickpea genotypes under the experimental conditions. Genotype x bacterium inoculation interaction was also statistically significant for wheat P concentrations (Table 2). The highest P concentration of wheat plant was obtained from followed chickpea variety of Aydın-92. The lowest P concentrations were obtained from followed chickpea varieties of Çağatay, Cevdet-98, Gökçe, Er-99, İzmir-92 and ILC-1482. Bacterium inoculation slightly increased P concentration in wheat plants, although the differences were not statistically significant. Considering the P treatments, P80 treatment resulted in higher P concentrations in wheat plants than P0 both in inoculated 0.154%) and non-inoculated (0.158%) conditions. In terms of inoculation x genotype combinations, the highest P concentration was obtained from the followed chickpea variety of Küsmen-99 under the non-inoculated condition.

Table 2: Residual effect of bacterium inoculated chickpea genotypes on P concentration of following wheat at different P levels (%)

Genotypes	Non-inoculated			Inoculated			Average
	P-0	P-80	Average	P-0	P-80	Av.	
Aydın-92	0.177	0.281	0.229 ad	0.223	0.297	0.260 ad	0.245 A
Meksika	0.195	0.253	0.224 ad	0.192	0.215	0.203 ad	0.214 AC
Diyar-95	0.162	0.223	0.192 ad	0.165	0.216	0.190 bd	0.191 AC
Sarı-98	0.165	0.212	0.188 cd	0.169	0.162	0.165 d	0.177 BC
Er-99	0.022	0.078	0.049 f	0.031	0.054	0.042 f	0.046 E
Aziziye-94	0.039	0.067	0.053 f	0.058	0.115	0.086 ef	0.070 DE
Cevdet-98	0.039	0.076	0.057 f	0.022	0.081	0.051 f	0.055 E
Gökçe	0.032	0.054	0.042 f	0.075	0.050	0.062 f	0.053 E
ILC-1482	0.047	0.049	0.048 f	0.025	0.014	0.019 f	0.034 E
İzmir-92	0.040	0.046	0.042 f	0.034	0.051	0.042 f	0.043 E
Çağatay	0.056	0.071	0.063 f	0.022	0.090	0.056 f	0.060 E
Konya	0.030	0.084	0.057 f	0.083	0.088	0.085 ef	0.071 DE
Gülümser	0.071	0.043	0.057 f	0.014	0.043	0.028 f	0.043 E
Akçin-91	0.030	0.058	0.043 f	0.099	0.266	0.182 cd	0.113 D
Y. Sıra	0.145	0.247	0.196 ad	0.179	0.219	0.199 ad	0.198 AC
Menemen-92	0.186	0.206	0.195 ad	0.219	0.321	0.270 ab	0.233 AB
Küsmen-99	0.199	0.343	0.270 a	0.186	0.193	0.189 cd	0.230 AC
Eser-87	0.186	0.214	0.199 ad	0.133	0.166	0.149 de	0.174 C
Uzunlu-99	0.146	0.246	0.196 ad	0.132	0.193	0.162 d	0.179 AC
Damla-89	0.159	0.301	0.229 ad	0.192	0.246	0.219 ad	0.225 AC
Average	0.106 b	0.158 a	0.132	0.113 b	0.154 a	0.133	

* Means with the same letter in the same column are not significant at 1 % level.

Significant differences were obtained for P contents of following wheat plants among the genotypes and P levels. Genotype x P levels interaction was found significant for P content

(Table 3). Wheat P contents varied from 0.59 to 8.29 mg·pot^{-1} depending on followed chickpea genotypes and different P treatments. The highest wheat P contents were obtained from the followed chickpea varieties of Meksika (8.29 mg·pot^{-1}1) and Aydın-92 (8.09 mg·pot^{-1}). Phosphorus contents of wheats were slightly increased (3.87 and 3.35 mg·pot^{-1}) followed the bacterium inoculated chickpea genotypes. Considering the P application, P80 treatment resulted in higher P content values in both inoculated (5.68 mg·pot^{-1}) and non-inoculated (4.96 mg·pot^{-1}) conditions than P0 (2.06 and 1.75 mg·pot^{-1}, respectively). The highest wheat P content of 10.44 mg pot-1 was obtained from followed inoculated chickpea variety of Aydın-92 (Table 3). Bacterium inoculation of chickpea did not significantly affect some properties of wheat plants growing after chickpea. However, there were some significant interactions between bacterium inoculation and genotype or phosphorus. Besides, organic nitrogen fixed through symbiotic process may positively effect on P uptake capacity of plants (Israel, 1987). As a matter of fact, the highest dry matter yield of wheat was obtained from followed chickpea variety of bacterium inoculated İzmir-92.

Table 3: Residual effect of bacterium inoculated chickpea genotypes on P content of following wheat at different P levels (mg·pot^{-1})

Genotype	Non-inoculated		Average	Inoculated		Average	Genotype x P		Average
	P-0	P-80		P-0	P-80		P-0	P-80	
Aydın-92	4.94	6.57	5.76 c-g	9.55	11.31	10.44 a	7.25 b-e	8.94 abc	8.09 A
Meksika	8.61	10.95	9.78 ab	3.75	9.86	6.81 b-e	6.19 c-f	10.41 ab	8.29 A
Diyar-95	2.83	9.33	6.08 c-f	3.54	5.29	4.42 d-k	3.19 f-i	7.32 b-d	5.25 BC
Sarı-98	2.34	7.16	4.76 c-k	2.39	7.30	4.82 c-j	2.34 f-i	7.23 b-e	4.78 BD
Er-99	0.42	3.30	1.86 g-l	0.72	1.78	1.25 i-l	0.58 i	2.54 f-i	1.55 E
Aziziye-94	0.46	2.83	1.65 h-l	0.81	4.19	2.51 f-l	0.64 i	3.52 e-i	2.07 DE
Cevdet-98	0.67	3.07	1.88 g-l	0.29	2.62	1.46 i-l	0.49 i	2.85 f-i	1.66 E
Gökçe	0.46	2.12	1.30 i-l	0.84	2.77	1.81 g-l	0.65 i	2.45 f-i	1.55 E
ILC-1482	0.58	2.51	1.55 i-l	0.44	1.32	0.89 jkl	0.52 i	1.92 ghi	1.21 E
İzmir-92	0.95	2.00	1.48 i-l	0.70	3.28	2.00 g-l	0.83 hi	2.64 f-i	1.73 E
Çağatay	0.30	2.40	1.36 i-l	0.19	2.11	1.15 i-l	0.25 i	2.26 ghi	1.25 E
Konya	0.60	3.25	1.93 g-l	0.94	3.14	2.05 g-l	0.78 hi	3.20 f-i	1.98 DE
Gülümser	0.39	1.19	0.84 jkl	0.16	0.53	0.35 l	0.28 i	0.91 hi	0.59 E
Akçin-91	0.42	1.14	0.79 kl	0.32	8.26	4.30 d-l	0.38 i	4.71 d-h	2.54 CE
Y. Sıra	1.38	6.93	4.16 d-l	3.75	7.39	5.58 c-h	2.57 f-i	7.17 b-e	4.86 BD
Menemen-92	1.33	4.11	2.73 f-l	5.24	10.23	7.74 a-d	3.29 f-i	7.18 b-e	5.23 BC
Küsmen-99	2.04	4.19	3.12 e-l	1.13	5.63	3.39 e-l	1.59 ghi	4.91 d-g	3.25 CE
Eser-87	2.17	4.36	3.27 e-l	1.58	3.39	2.49 f-l	1.88 ghi	3.88 d-i	2.88 CE
Uzunlu-99	1.47	8.58	5.03 c-i	2.12	14.75	8.44 abc	1.80 ghi	11.67 a	6.73 AB
Damla-89	2.57	13.05	7.82 a-d	2.97	8.47	5.62 c-g	2.67 f-i	10.76 ab	6.71 AB
Average	1.75 b	4.96 a		2.06 b	5.68 a				

* Means with the same letter in the same column are not significant at 1 % level.

Conclusions

Residual effect of bacterium inoculated and non-inoculated chickpea genotypes on dry matter yield and P uptake of following wheat plants were investigated. Bacterium inoculation did not have any effect on P concentration and P content. However, interactions between genotype and P rates were sometimes significant. Determining the nutrient use efficiency and residual effects of plant on the following crop was a significant issue. There are two types of genotypes according to their nutrient uptake and use efficiency; "efficient" and "non-efficient". Efficient genotypes have superior abilities to absorb nutrients through the roots and to metabolize them, and thus they allow less fertilizer use (Graham, 1984). Chickpea and wheat plants more often follow each other in dryland rotation systems. In the areas, in which these systems are applied, the amount of available water is the main factor limiting the yield. Plant genotypes that can use the scarce water and nutrients better will be more preferred than other genotypes. Chickpea genotypes with good adaptation to dryland conditions will provide a better growing condition for the following wheat crops by supplying more organic matter and plant nutrients to the soil. Thus, not only will the performance of crops be improved, but also less inorganic fertilizer will be needed, and less environmental pollution from excess fertilizer. The results have also revealed that selection of chickpea genotypes for residual P use effect on the following wheat plants will have a valuable contribution for breeding studies. Similar studies on other crop species will be useful for sustainable organic agriculture. This practice will also be valuable for background of sustainable soil fertility and organic agriculture.

Footnote

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