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Full Length Research Paper

Residual effect of bacterium (*Rhizobium* spp.) inoculated chickpea (*Cicer arietinum* L.) genotypes on nitrogen (N) use efficiency of some wheat plants

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Chickpea is an important legume in crop rotation due to its nitrogen (N) fixing ability. It takes advantage of soil profile thereby providing nitrogen to other crops. Determination of amounts of deposited N and the efficient use of different chickpea genotypes on the study crops will be beneficial for plant breeding, in the use of fertilizer and sustainable agriculture. For the present investigation, 20 different chickpea genotypes made up of bacteria inoculated and non-inoculated with different N rates were used in pot experiment, in which a calcareous soil was used. Experimental design was completely randomized blocks with three replications and nitrogen was applied as ammonium nitrate in 0, 60 mg N kg^{-1} rates. Phosphorus fertilizer as phosphoric acid (H_3PO_3) at the rate of 80 mg P kg^{-1} was applied to all pots for optimum growth. Soil in pots was incubated after the harvest of chickpea plants. After incubation, Ziyabey 98 wheat variety was planted in the same pots to determine the subsequent effect of bacterium inoculated chickpea genotypes on N use efficiency of the studied plants without N fertilization. Wheats were harvested about seven weeks later and dry matter yield of plant, N concentration and amounts of N-uptake by wheat were determined. In addition, parameters of the agronomic N efficiency and the average efficiency index were calculated to show the differences between chickpea genotypes. Chickpea genotypes that were previously cultivated in pots significantly affected the dry matter yield of wheat. It can be said that bacterium inoculation does not positively affect N use efficiency. Dry matter yields of wheat that was planted in pots from which Gülümser, Cağatay, Akcin-91 and Gökce chickpea genotypes were previously harvested were found to be higher than the other genotypes. It was pointed out that chickpea genotypes leaves different levels of N residue in soil. The selected chickpea genotypes will be excellent materials for plant breeders and biotechnologists to develop genotypes with efficient N-uptake and utilization capacities, it is also important for sustainable nutrient elements circle of soils.

Key words: Chickpea genotypes, bacteria inoculation, residual effect, nitrogen use efficiency.

INTRODUCTION

The excessive use of nitrogen fertilizer for obtaining higher product yield in agricultural production affects the environment and also farmers from the point of view of cost expenses. Therefore, varieties that increase nitrogen content of soil and utilizes nitrogen more effectively should be used. Furthermore, application of different and appropriate plant growing systems within a sustainable plant growing system will positively affect the quality of the soil and plant nutrient dynamics. This is caused by the demands of different nutrient matter

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on the plants under rotation, rooting depths, differences between residue leaving characteristics and the interactions caused by different partnerships established by them through microbial activities (Drinkwater et al., 1998). Poly-cultural agricultural practice (multi-variety) rather than mono-cultural agricultural practice (single variety) reduces soil fatigue and brings a dynamic structure to it. Various nutrient elements remain due to some residues left by plants in sowing rotation systems. It has been reported that cereal production increases when they are planted after legumes and this increase in production varies depending on the legume varieties used as pre-plant (Rushell, 1961).

Chickpea has 630 000 ha of acreage and 650 000 tones of production in Turkey (Anonymous, 2006). Farmers in Turkey grow chickpea in small areas mainly for their own needs. Chickpea is the second most drought tolerant plant after lentil. It can be grown on many kinds of soils. However, it can grow on well-drained, slightly acidic or alkaline pH= 6-8 limed and low yielding dry land areas. It is drought tolerant because of its relatively small plants and taproot system. It can fix free nitrogen in the air to the soil via the *Rhizobium* bacteria in its roots. Its farming is easy and growth period is short. All these factors make it a significant crop that can enter into cereal-fallow rotation system (Sepetoğlu, 1994; Azkan, 1999).

Chickpeas supply most of their nitrogen demands through fixation beside soil. However, cereals and the oily seed plants deplete useful soil nitrogen. Eighty per cent of the air is nitrogen (N_2); however, plants cannot use atmospheric nitrogen directly to synthesize protein. Nitrogen, which is naturally in gas state, should be converted into the forms, which can be used by plants (Silva and Uchida, 2000). Nature has an alternative method to enrich nitrogen resources and to provide nitrogen for plants. Most of the agricultural products in legume family take the required nitrogen for growing from the atmosphere through biologic nitrogen fixation. A legume plant and rhizobium bacteria in the nodules in the legume's root survive symbiotically. Legumes fix 5-19 kg/da of N (Gecit, 1995); 5-15 kg/da (Azkan, 1999) into the soil per year through this process. Single-year legumes may contribute to total N content of soil (Herridge et al., 1995), other researches reported that three-year legumes-wheat rotation changes and increases mineral N content of soil (Bidlack et al., 2007)

Nitrogen management has a key role in improving product quality (Campbell et al., 1995). Optimal N management will be affected by product variety and rotation and N level in soil because N in previous products returns to the system (Grant et al., 2002). Graham (1984) reported that the genotypes, which use nutrients efficiently, are less affected by deficiency of one or more nutrients in soil compared with others.

Legumes increase their growth by activating residual phosphorus through their roots besides bringing nitrogen to soil (Nuruzzaman et al., 2005). Dahiya and Singh (1993) determined that nitrogen positively affects growth of vegetative parts of chickpea plant and nitrogen-phosphorus interaction in soil is also required for plant growth. In this way, nitrogen-phosphorus interaction in soil will be affected positively.

Varied product rotations may increase vegetative efficiency potential by affecting vege-tative diseases, foreign weeds, root spread, water use and usability of nutrients. Selecting chickpeas using highly efficient nitrogen and estimating nutrient element amount left after harvest will help determine the amount of nitrogen fertilizer to be applied on plants and for efficient nitrogen use. Selecting these varieties will be useful for variety selection of nutrient element studies to be done in the future on plant treatment, which is an important matter of field plants.

MATERIALS AND METHODS

A pot experiment, based on a completely randomized design with three replications, was conducted using a calcareous soil. In the first part of the study twelve different chickpea genotypes, Aydın-92, Meksika, Diyar-95, Sarı-98, Er-99, Aziziye-94, Cevdet-98, Gökce, ILC-1482, İzmir-92, Cağatay, Konya, Gülümser, Akcin-91, Yerli sıra, Menemen-92, Küsmen-99, Eser-87, Uzunlu-99 and Damla-89 were used under the bacterium inoculated and non-inoculated conditions for this study. Nitrogenous fertilizer as ammonium nitrate at the levels of 0 and 60 mg N kg^{-1} was applied to the pots. Phosphorus fertilizer as H_3PO_3 at the level of 80 mg P kg^{-1} was applied to all pots for normal growth. In addition, a basal dressing of some micro nutrients was applied to all pots for sufficient plant growth. In the second part of study after harvesting of chickpea genotypes, soils in pots were mixed and left for incubation.

Ziyabey 98 wheat variety was planted in the same pots to determine the subsequent effect of bacterium inoculated chickpea genotypes on N use efficiency of the subsequent plants. In order to see the effect of N, only phosphorus fertilizer as H_3PO_3 at the level of 80 mg P kg^{-1} was applied and some micro nutrient elements were given to all pots. Plants were harvested early, and then they were dried in an oven until they reach a constant weight. Total N concentrations in aerial parts of the plants were also determined. The analysis for N concentration in the top of plants was made using Kjeldahl method (Chapman, 1961). Some properties of chickpea genotypes used for the experiment are presented in Table 1.

In the experimental soil, available P analysis was made using the method of Olsen et al. (1954). Also, the textural analysis with a Bouyoucos hydrometer Gee and Bouder, (1986); organic matter content with the Walkley-Black method Jakson, (1956); exchange-able potassium and C.E.C. Richards (1954); $CaCO_3$ Chapman (1961) and pH McLean (1986) values were determined. Experi-mental data were subjected to the statistical analysis of variance using MSTAT package program, and the mean scores were separated by Duncan's multiple range test. Some linear and polnomial regression analyse were made for the genotypes and N levels using the Stat-Most programme (StatMost, 1995).

Table 1. Some properties of chickpea genotypes used for the experiment.

Genotypes	1000 Seed weight (g)	Resistance to A. Blight
Aydın-92	350	T
Menemen-92	450	T
Akcin-91	400 - 430	T
Aziziye-94	500	R
Damla-89	450 - 500	T
Er-99	470 - 480	R
Uzunlu-99	500 - 510	T
Gökce	440 - 460	R
Küsmen-99	500 - 510	R
İzmir-92	450	T
Sarı-98	500 - 510	T
Diyar-95	-	-
Cevdet-98	440 - 490	T
Cağatay	470 - 500	T
Gülümser	450 - 475	T
Eser-87	-	T
ILC-1482	-	R
Populations		
Konya	-	S
Meksika	-	S
Yerli Sıra	-	S

T: tolerance, R: resistance, S: susceptibility.

Dry weight (DM) and total N content of the plants were used to calculate the efficiency index parameter (dm^2/total N content) for classification of genotypes (adapted from Siddiqi and Glass (1981); (Furlani et al., 2001). The calcareous soil used in this study was clay-loam in texture with 36, 34 and 30% clay, silt and sand, res-pectively, and the calcium carbonate content was 200 g kg^{-1}. It had also the following chemical properties: pH (soil: H_2O = 1:2.5) = 8.05; organic matter content= 1.7%; available phosphorus= 7.03 mg P kg^{-1}; exchangeable potassium= 6.4 me 100 g^{-1}; and cation exchange capacity= 35.2 me 100 g^{-1}.

RESULTS AND DISCUSSION

Dry matter yield, N and total N content of wheat grown following chickpea genotypes

The results relating to dry matter yield, N concentration and N amount depletion of wheat plant grown following 20 different chickpea genotypes on which two nitrogen doses and bacteria-inoculation were applied are seen on Tables 2, 3 and 4. According to statistical review, genotype, nitrogen applications, genotypes x inoculation and genotypes x nitrogen applications caused variations in wheat plant's dry matter yields at a significance degree of 1% and genotype x inoculation caused variations at a significance degree of 5%. However, other characteristics did not have any influence. Dry matter contents of wheat plant grown in the pots in which chickpea plant had grown previously and on which nitrogen was applied increased significantly compared with those on which nitrogen was not applied. Growth that occurred in vegetative parts of the plant was related to the nutrients in soil and especially nitrogen presence. Roots were examined during the tests in a way that the chickpea genotypes on which nitrogen was and was not applied as well as inoculated and not inoculated were represented. It was observed in this review that, root weights and growths of the plants on which nitrogen was applied and inoculated were better.

Roots left inside soil after plants are harvested contain approximately N at 5-20%. Organic materials having high nitrogen content decompose in shorter time inside soil. (Cabon/nitrogen)C/N ratio was 13/1 in legumes' roots and they can be decomposed by microorganisms within 1-2 weeks under appropriate conditions (Akdağ, 1996). Legumes satisfy most of their nitrogen demands from the atmosphere under appropriate conditions. Some of this nitrogen is removed by plants while other parts become free in organic form due to decomposition of roots inside soil. This residual nitrogen causes the increase in yield of subsequent plants. Differences exist from the point of view of fertilizer use efficiency even between different genotypes of the same plant variety (Torun and Cakmak, 2004).

According to the statistics review, N contents of wheat plant are not affected by varieties and inoculation. Nitrogen applications, genotypes × nitrogen applications and genotypes × nitrogen applications × bacteria applications cause variations at a significance

Table 2. Residual effect of bacterium inoculated chickpea genotypes on dry matter of following wheat at different N levels (g pot^{-1}).

Genotypes	B (-)			B (+)			G xN		
	N0	N60	Mean	N0	N60	Mean	N0	N60	Gen. Mean
Aydın	2.66	4.30	3.48 ac	2.93	4.20	3.56 ac	2.80 ce	4.25 ae	3.52 B
Meksika	2.53	3.26	2.90 bc	2.33	3.76	3.05 bc	2.43 ce	3.51 be	2.97 C
Diyar-95	2.50	3.73	3.12 bc	2.16	3.73	2.96 bc	2.33 ce	3.73 ae	3.03 BC
Sarı-98	2.70	4.20	3.45 ac	2.63	3.23	2.93 bc	2.66 ce	3.71 ae	3.19 BC
Er-97	2.60	3.36	2.98 bc	2.96	3.96	3.46 ac	2.78 ce	3.66 ae	3.22 BC
Aziziye-94	2.90	4.60	3.75 ac	2.70	3.76	3.23 ac	2.80 ce	4.18 ae	3.49 B
Cevdet	2.80	4.13	3.46 ac	2.80	3.33	3.07 bc	2.80 ce	3.73 ae	3.27 B
Gökce	3.26	4.43	3.85 ac	3.56	4.13	3.85 ac	3.41 be	4.28 ae	3.85 AB
ILC-1482	2.10	3.20	2.65 c	3.00	4.86	3.93 ac	2.55 ce	4.03 ae	3.29 B
Izmir	4.43	3.36	3.90 ac	3.30	3.73	3.52 ac	3.86 ae	3.55 be	3.71 B
Cağatay	2.36	5.46	3.92 ac	2.86	5.23	4.05 ac	2.61 ce	5.35 ab	3.98 AB
Konya	3.00	3.43	3.22 ac	3.80	5.06	4.43 ab	3.40 be	4.25 ae	3.82 AB
Gülümser	2.66	5.00	3.83 ac	2.53	7.23	4.88 a	2.60 ce	6.11 a	4.36 A
Akcin-91	3.76	5.20	4.48 a	2.40	4.33	3.38 ac	3.08 be	4.76 ad	3.92 AB
Y. Sıra	2.90	4.93	3.92 ac	2.40	4.80	3.60 ac	2.65 ce	4.86 ac	3.75 B
Menemen-92	1.76	3.23	2.50 c	2.50	4.36	3.43 ac	2.13 e	3.80 ae	2.97 C
Küsmen-99	2.70	4.53	3.62 ac	2.40	4.63	3.52 ac	2.55 ce	4.58 ae	3.56 B
Eser-87	1.86	4.30	3.08 bc	2.23	3.63	2.93 bc	2.05 e	3.96 ae	3.00 C
Uzunlu-99	1.76	4.20	2.98 bc	2.23	3.43	2.83 bc	2.00 e	3.81 ae	2.91 C
Damla-89	2.10	2.80	2.45 c	2.40	4.83	3.62 ac	2.25 de	3.81 ae	3.03 C
Mean	2.67	4.08		2.71	4.31				
Bac. Mean		3.37					3.51		
N Mean.		2.69 B					4.20 A		

There are no significant difference among means of like letter to be showed in like column. F-values; Genotypes: 2.8832**; bacterium applications (B): N.S.; C×B: 2.0422*, N applications. (N): 204.6978**, G×N: 2.8204**; B×N: N. S..D; G×B×N: 1.5803 N.S., **P < 0.01, *P < 0.05., N.S: Not significant.

Table 3. Residual effect of bacterium inoculated chickpea genotypes on N content of following wheat at different N levels (%).

Genotypes	B (-)			B (+)			G ×N		
	N0	N60	Mean	N0	N60	Mean	N0	N60	Gen. M.
Aydın	1.53 ag	2.74 af	2.13	1.01 eg	2.68 ag	1.85	1.27 cf	2.71 ac	1.99
Meksika	1.06 eg	2.99 ac	2.02	1.08 eg	2.55 ag	1.81	1.07 df	2.77 ac	1.92
Diyar-95	1.14 cg	3.01 ab	2.08	1.14 cg	2.79 ae	1.97	1.14 df	2.90 a	2.02
Sarı-98	0.91 fg	2.55 ag	1.73	1.31 ag	3.12 a	2.22	1.11 df	2.83 ab	1.97
Er-97	0.99 eg	2.75 af	1.87	1.47 ag	1.41 ag	1.44	1.23 cf	2.08 af	1.65
Aziziye-94	0.92 eg	2.34ag	1.63	1.11dg	2.30ag	1.71	1.02 df	2.32 af	1.67
Cevdet	0.89fg	1.85 ag	1.37	0.82 g	2.95 ad	1.89	0.86f	2.40 af	1.63
Gökce	0.91 fg	2.68 ag	1.79	1.75 ag	1.64 ag	1.70	1.33 bf	2.16 af	1.74
ILC-1482	1.43 ag	2.05ag	1.74	1.02eg	1.40 ag	1.21	1.23 cf	1.72 af	1.47
Izmir	2.02 ag	1.30 ag	1.66	1.84 ag	2.02 ag	1.93	1.93 af	1.66 af	1.79
Cağatay	1.26 bg	2.56 ag	1.91	0.95 eg	2.47 ag	1.71	1.10 df	2.51ad	1.81
Konya	1.19 bg	2.31 ag	1.75	1.92 ag	2.53 ag	2.22	1.55 af	2.42 af	1.98
Gül ümser	1.34 ag	2.46 ag	1.90	1.43 ag	2.44 ag	1.93	1.39 af	2.45 ae	1.92
Akcin-91	1.25 bg	2.12 ag	1.68	1.00 eg	2.26 ag	1.63	1.13 df	2.19 af	1.66
Y. Sıra	0.83 g	2.37 ag	1.60	1.00 eg	2.42 ag	1.71	0.92 ef	2.39 af	1.66
Men. 92	1.31 ag	2.08 ag	1.69	1.15 cg	2.51 ag	1.83	1.23 cf	2.29 af	1.76
Küsm-99	1.48 ag	3.01 ab	2.24	1.22 bg	1.77 ag	1.50	1.35 bf	2.39 af	1.87
Eser-87	1.63 ag	2.04 ag	1.83	0.89 fg	1.87 ag	1.38	1.26 cf	1.96 af	1.61

Table 3. Contd.

Uzunlu-99	1.11 dg	2.39 ag	1.75	1.03 eg	2.27 ag	1.65	1.07 df	2.33 af	1.71
Daml-89	0.89 fg	2.43 ag	1.66	1.18 bg	1.97 ag	1.57	1.03 df	2.19 af	1.62
Mean	1.21	2.40		1.22	2.27				
Bac. Mean		1.81					1.75		
N Mean.		1.21 B					2.34 A		

(a) There are not difference among means of like letter to be showed in like column. F-values, Genotypes (G): N.S., Bacterium applications (B): N.S.; GxB: N.S., N applications (N): 344.5327**; GxN: 3.1534**; BxN: N.S; GxBXN: 2.1299**, **P < 0.01, *P < 0.05, N.S: Not significant.

Table 4. Residual effect of bacterium inoculated chickpea genotypes on total N content of following wheat at different N levels (mg pot^{-1}).

Genotypes	B (-)			B (+)			G xN		
	N0	N60	Mean	N0	N60	Mean	N0	N60	Gen. Mean
Aydın	41.00	118.52	79.76	29.88	112.91	71.40	35.44 c	115.72 ac	75.58
Meksika	27.25	96.09	61.67	24.53	92.19	58.36	25.89 c	94.14 ac	60.02
Diyar-95	28.60	110.18	69.89	25.16	100.83	62.99	26.88 c	106.01 ac	66.44
Sarı-98	142.47	106.84	124.6	35.50	98.41	66.95	88.98 ac	102.62 ac	95.80
Er-97	26.08	94.70	60.39	42.55	56.45	49.50	34.31 c	75.57 ac	54.94
Aziziye-94	27.11	108.38	67.74	30.22	86.17	58.19	28.66 c	97.27 ac	62.97
Cevdet	25.49	77.66	51.57	23.07	99.09	61.08	24.28 c	88.37 ac	56.33
Gökce	29.87	119.52	74.69	64.93	73.08	69.00	47.40 bc	96.29 ac	71.85
ILC-1482	34.75	72.17	53.46	31.35	72.04	51.70	33.05 c	72.11 ac	52.58
Izmir	96.52	47.64	72.08	66.35	78.18	72.26	81.43 ac	62.91 ac	72.17
Cağatay	30.25	141.14	85.70	27.64	130.44	79.04	28.94 c	135.79 ab	82.37
Konya	29.19	76.12	52.96	71.97	130.16	101.06	50.58 bc	103.44 ac	77.01
Gülümser	36.15	119.55	77.85	33.61	178.83	106.22	34.88 c	149.19 a	92.03
Akcin-91	52.42	109.35	80.89	23.63	97.11	60.37	38.03 c	103.23 ac	70.63
Y. Sıra	23.96	120.51	72.23	24.50	115.69	70.09	24.23 c	118.10 ac	71.16
Men.92	23.44	66.43	44.93	29.56	107.70	68.63	26.50 c	87.06 ac	56.78
Küsmen-99	39.16	135.95	87.56	29.33	84.61	56.97	34.25 c	110.28 ac	72.26
Eser-87	28.43	91.37	59.00	19.65	68.67	44.16	24.04 c	80.02 ac	52.03
Uzunlu-99	20.27	99.94	60.10	23.37	77.98	50.67	21.82 c	88.96 ac	55.39
Damla89	18.90	67.05	42.97	27.23	93.88	60.55	23.06 c	80.47 ac	51.76
Mean	39.07	99.03		34.20	97.72				
Bac. Mean		69.05					65.96		
N Mean.		36.63 B					98.38 A		

There are not difference among means of like letter to be showed in like column. F-values, Genotypes (G): N.S, Bacterium applications (B): N.S; GxB: N.S., N applications (N): 184.8341**; GxN: 2.1440**; BxN: N.S.; GxBxN: N.S., **P < 0.01, *P < 0.05, N.S: Not significant.

degree of 1%. This is seen in Table 3. Considering all nitrogen application mean, N content of the wheat plant grown in the pots on which nitrogen had been applied was higher compared with those grown in pots on which nitrogen had not been applied. This indicates that the wheat plant benefited from nitrogen existing in the pots. The mean was 2.34% in case of nitrogen applications while the mean scores were 1.21% in pots where nitrogen was not given. The more the plant removes nutrients from soil the more it grows and therefore, its yield will also be higher.

Considering the average nitrogen amounts that were depleted by the wheat plants, nitrogen amounts that were depleted by the wheat plants grown in the chickpea pots on which nitrogen had been applied were effective at a statistical significance degree of 1% compared with those on which nitrogen had not been applied. Genotypes and inoculation did not affect the

Table 5. Agronomic N efficiency and average efficiency index.

Genotypes	Agronomic N efficiency (%)[a]		Average efficiency index (EI)[a]	
	B^- (N0/N60)	B^+ (N0/N60)	B^-	B^+
Aydin	61.9	69.7	0.160	0.220
Meksika	77.6	61.9	0.170	0.185
Diyar-95	67.0	57.9	0.165	0.161
Sarı-98	64.2	81.4	0.108	0.150
Er-97	77.4	74.7	0.189	0.241
Aziziye-94	63.0	71.8	0.252	0.208
Cevdet	67.8	84.1	0.263	0.225
Gökce	73.5	86.1	0.259	0.214
ILC-1482	65.6	61.7	0.134	0.307
Izmir	131.8	88.4	0.219	0.171
Cağatay	43.2	54.7	0.197	0.210
Konya	87.5	75.1	0.231	0.198
Gülümser	53.2	34.9	0.243	0.241
Akcin-91	72.3	55.4	0.258	0.218
Y. Sıra	58.8	50.0	0.276	0.217
Menemen-92	41.9	57.3	0.144	0.193
Küsmen-99	59.6	51.8	0.168	0.210
Eser-87	43.2	61.4	0.161	0.222
Uzunlu-99	41.9	65.0	0.164	0.181
Damla-89	75.0	49.6	0.174	0.229

depleted N amounts while nitrogen applications, nitrogen × genotype, influenced them at a significance degree of 1%. Considering nitrogen amounts that were depleted by the wheat plants, nitrogen amounts that were depleted by the wheat plants grown in the chickpea pots on which nitrogen had been applied previously were higher. This indicates that the previously grown chickpea plant removed the existing nitrogen in soil fleaving only N in the soil. Thus, it provided the required N for growth of the next plant.

Residual nutrient elements left by the previously grown plant for the next plant will ensure that the next plant grows sufficiently along with the fertilizers to be supplied. Genotype × nitrogen applications interaction affected dry matter content of the wheat statistically. This indicates that more nitrogen were left by the chickpea genotypes due to the nitrogen applications on the wheat plant grown after them and as a result, dry matter content of the wheat plants increased. This suggests that chickpea genotypes produced different responses to nitrogen applications. Only nitrogen fertilizer was applied at the first stage of the study; however, wheat plant was not fertilized by nitrogen.

Agronomic efficiencies of the wheat plant was examined depending on the increase in its dry matter contents due to the nitrogen fertilizer applications applied previously to determine which of the chickpea genotypes leave more nitrogen to soil or which of the genotypes has higher nitrogen use efficiency in the study. Agronomic N efficiency varied between 41.9 and 131.8% at not-inoculated and N-60 levels and between 34.9 and 88.4% at inoculated and N-60 levels. Dry matter content of the wheat grown in the pots of only İzmir chickpea genotype did not increase despite nitrogen application at not-inoculate and N-60 levels. An increase occurred in dry matter content of the wheat plant grown after the inoculated chickpea genotypes and N-60 levels were compared with the initial nitrogen level (N-0). These results indicate that chickpea genotypes give positive responses to inoculation and the nitrogen applied.

Efficiency index varied depending on dry matter yield and depleted N content of the plant. The highest average efficiency index that was found in the wheat plants grown after non-inoculated chickpea genotypes was found in the wheat plants grown after Y. Sıra, Cevdet, Akcin-91 and Gökce chickpea genotypes (Table 5). On the other hand, the lowest average efficiency index was determined in the wheat plants grown after yellow-98 chickpea genotype. The highest average efficiency index that was found in the wheat plants grown after inoculated chickpea genotypes was also found in the wheat plants grown after ILC-1482, Gülümser and Er-97 chickpea genotypes while the lowest average efficiency index was determined in the wheat plants grown after Sarı-98 chickpea genotype.

(a) Agronomic N efficiency = % value related to the response of a genotype to supplied N level. In N efficient genotype, % N efficiency value is higher, which means that the genotype has lower response or non-response to the supplied N levels.

(b) Efficiency index (EI) = dry matter yield^2/total N content, and serves to select wheat genotypes with improved N utilization characters as ER (efficient-responsive), ENR (efficient non-responsive), IR (inefficient responsive) and INR (inefficient responsive).

Conclusion

Differences exist from the point of view of nutrient elements use efficiency, water use efficiency and responses to cultural practices even between different genotypes of the same plant variety. Chickpea genotypes existing in this study gave different responses to nitrogen fertilizing and inoculation. Consequently, they left nutrient elements at different levels for the next plants. We may think that chickpea plant can benefit more from nutrients and can also leave more nutrients for the next plants if the conditions which can make bacterial activities work better are provided in the agricultural production. To this extent, developing a fertilizing program depending on the plants to be produced and practices in addition to traditional fertilizing will be useful in achieving appropriate results.

Bacterial inoculation under the test conditions did not affect the characteristics under study at a statistically significant degree. High lime content, high pH degree and low organic matter content in the test soil probably prevents bacterial activity. This clearly evidences the relation between soil conditions and bacterial activity. Using chickpea genotypes with high response to nitrogen and bacteria application on the fields on which chickpea are grown will cause yield increase. This is because these genotypes use nutrient elements in soil more efficiently; thereby leading to an efficient use of more N resources.

Determination and application of bacteria strains that can work under these conditions will be helpful for yield increase. In the studies on genotypes nutrient elements, microelements such as molybdenum and cobalt should be taken under study beside N-P.

Chickpea plant contributes significantly to vegetative production sustainability indirectly by leaving nutrients in soil for the plants to be grown after it. This indicates that legumes, which fix nitrogen to soil and supply nutrients to soil by decomposition of roots, should be planted espe-cially in October shift systems. It may be recommended that the effective genotypes mentioned in this study are developed considering their agricultural characteristics and are made to prevail more. Considering this will contribute to more efficient nutrient use especially in treatment studies. Legumes-wheat rotation should be executed in a field study by employing the genotypes highlighted in this study. This will be helpful in achieving the aim of the study and detecting insufficiencies under field conditions.

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