Effects of Different AMF Species on Some Bean Cultivars Grown in Salty Conditions

Önder Türkmen
Department of Horticulture Agricultural Faculty
Selcuk University, Konya, Turkey
turkmen@selcuk.edu.tr

Vahdettin Çiftçi
Department of Field Crops Agricultural Faculty
Yuzuncu Yil University, Van, Turkey

Çeknas Erdinç
Department of Horticulture Agricultural Faculty
Yuzuncu Yil University, Van, Turkey

Suat Şensoy
Department of Horticulture Agricultural Faculty
Yuzuncu Yil University, Van, Turkey

Abstract: This study was carried out to determine the effects of three different Arbuscular Mycorrhizal Fungi (AMF) species (*Glomus mosseae, G. intraradices* and *G. fasciculatum*) on the growth and nutrient contents of four bean cultivars (Onceler, Seker, Terzibaba and Sehirali) grown under salt stress. The constant amount of NaCl (50 ppm) was added the autoclaved growth medium containing 1:1:1: ratios of soil, sand, and manure. The five g (25 spores g^{-1}) of inoculum was placed in the seedling growth medium before the seeds were sown. At the end of the study, some nutrients such as N, P, K, Ca, Mg, Fe, Cu, Mn, and Zn and plant growth parameters such as shoot height, stem diameter, root length, leaf number, leaf area, and dry and fresh weights of shoots and roots were investigated. Moreover, the plant colonization rates of AMF species were determined. The AMF species had positive effects on the plant growth and nutrient intake. Among the bean cultivars, Onceler and Terzibaba, and among the AMF species, *G. mosseae*, had the best results for plant growth.

Introduction

Bean is the most widely produced legumes in the world, especially in Asia and South America (Ozdemir, 2002). Fresh bean productions of the world and Turkey (the second biggest producer) are 6.37 and 0.49 million tons, respectively (Anonymous, 2007). Bean is easily produced in all parts of Turkey and has an important place in human consumption.

Soil salinity is one of the limiting environmental factors for agricultural productivity in the world and Turkey and more than one third of the world's agricultural land faces with this problem (Greenway & Munns, 2000, Kaynak et al. 2000). Turkey faces with salinity problem in 32.5 % of its irrigated land (1.5 millions ha). Especially seed emergence and seedling growth are adversely affected in salt accumulated soil. Salinity may occur when there is irregular irrigation, inadequate drainage, wrong fertilizer application, and it extremely increases especially in protected cultivation. Some physiological disorders and even plant dies might be observed due to high osmotic pressure and toxic effects of Na^+ and Cl^- ions (Franca Dantas et al. 2007; Greenway & Munns, 1980; Ekmekçi et al. 2005; Kaynak et al. 2000). In soils having salinity problems, there are accumulations of Na^+ and Cl^- ions, increase in Na^+:Ca^{2+}, Na^+:K^+, Ca^{2+}:Mg^{2+} and Cl^-: NO^{-3} ratios; consequently, there are ion toxicity and imbalance (Hu & Schmidhalted, 2005). Increase in Na^+ inhibits K^+ uptake, and Increase in Cl^- reduces NO^{-3} uptake (Turkmen et al. 2005). Higher amounts of salty substances in soil hinder water uptake and destroy soil structure (Ekmekci et al. 2005).

Plant species are called salt intolerant if they can only survive in EC values ranged from 0 to 4 ds m^{-1} (Ekmekci et al. 2005). Bean is a salt intolerant plant species. The significant yield losses are observed in bean even at below 2 ds m^{-1} (Gama et al. 2007). The yield loss migth be 50 % above2 ds m^{-1} EC values (Ekmekci et al. 2005).

The harmful effects of salinity can be lessened with the use of tolerant cultivars beside several cultural practices. Moreover, the humic substances in the soil (Türkmen et al., 2005) and some useful microorganisms such as arbuscular mycorrhizal fungi (AMF) can give encouraging results in salt tolerance (Türkmen et al., 2005; Gosling et al. 2006; Aroca et al., 2007; Türkmen et al., 2008).

AM Fungi are the most widespread root fungal symbionts and are associated with the vast majority of higher plants (Selvaraj & Chellappan, 2006). AMF enable plants to cope with detrimental environmental conditions; therefore, AMF increase plant growth and yield (Bolandnazar et al., 2007). Approximately 96 % of the plants in the world is dependent and associated with AMF (Quilambo, 2003;Ortas & Akpınar, 2004). The degree of this dependence varies among the plant species. Bean is one of the species having high mycorrhizal dependency (Ortas & Akpınar, 2004). While plants provide carbohydrates to AMF, AMF alleviate certain nutrient deficiencies by increasing nutrient uptake (Ortas & Akpınar, 2004; Selvaraj & Chellappan, 2006). AMF's hyphae improve the uptake of some water insoluble nutrients by the help of their enzymatic activities and by the alteration of physical and chemical properties in the soil (Abdelhafez & Abdel-Monsief, 2006). Beside improving soil properties, AMF also enable plants to cope with both biotic and abiotic stresses (Aroca et al., 2007; Ortas & Akpınar, 2004). Salinity is among these troubles (Juniper & Abbott, 2004).

It was observed that AMF could be effective for salt tolerance in bean (Rabie, 2005; Trujillo, 2006). Therefore, this study was carried out to determine the effects of different AMF species on the seedling growth and nutrient contents of some bean cultivars grown under salt stress.

Material and Methods

Four bean cultivars were examined, as follows: (1) Onceler; (2) Seker; (3) Terzibaba; (4) Sehirali. Three AMF inoculums were tested in the study -*Glomus intraradices* (Gi) and *G. mosseae* (Gm), and *G. fasciculatum* (Gf). Inocula consisted of spores, extraradical mycelium and mycorrhizal roots

Growth medium was comprised of an autoclaved mixture of sand, manure and soil with a pH of 8.70 and a composition of 3.19% organic matter, 0.0032% salt (Kacar, 1994). The experiment used an 4x4 factorial design (four bean genotypes, three AMF plus one control) with four random replications of ten pots (no drainage) each, for a total of 640 pots. One bean seed was sown per pot, each of which contained 250 cm^3 of sterilized growth medium. In the AMF inoculated samples, 5 g (25 spores g^{-1}) of inoculum was placed in the growth medium before the seeds were sown (Demir & Onogur, 1999). The constant rate of 50 ppm NaCl was added to the growth medium after seed sowing. Seedlings were thinned to one per pot shortly after seed emergence, placed in a growth chamber at a temperature of 22 ± 1^0C with 12 h fluorescent illumination (8000 lx light intensity), and irrigated with distilled water. Plants were harvested 6 weeks after seed sowing and inoculation.

At the end of the study, some nutrients such as N, P, K, Ca, Mg, Fe, Cu, Mn, and Zn and plant growth parameters such as shoot height, stem diameter, root length, leaf number, leaf area, and dry and fresh weights of shoots and roots were investigated. Moreover, the plant colonization rates of AMF species were determined after harvesting. Samples were then oven-dried at 68 ^{0}C for 48 h, ground, and nitrogenous (N) content was analyzed with Kjeldahl method; phosphorous (P) content was measured with spectrophotometer (Kacar, 1984). K, Ca, Mg, Fe, Cu, Mn, and Zn contents were analyzed using the Association of Official Analytical Chemists' method with atomic absorption spectrophotometer (AOAC, 1990).

Bean roots were dyed to detect AMF presence, which was determined using a modification of Phillips and Hayman's (1970) method, and the percentage and intensity of mycorrhizal colonization was estimated using the Grid Line Intersect Method (Giovanetti & Mosse, 1980).

Data were analyzed using the SAS statistical program, with variance analysis conducted for all data. Differences between treatments were determined using Duncan's Multiple Range Test (SAS Software, 1997).

Results

Plant Growth Parameters

At the end of the study, the significant ($P<0.01$) differences were observed among bean cultivars, AMF species and bean cultivar x AMF species interaction for fresh shoot weight [Table 1]. While Onceler cv had the highest fresh shoot weight (5.08 g $plant^{-1}$), Sehirali cv had the lowest fresh shoot weight (3.72 g $plant^{-1}$). While Gm had the highest fresh shoot weight (5.10 g $plant^{-1}$), Gf had the lowest fresh shoot weight (3.96 g $plant^{-1}$). The Terzibaba cv x Gm had the highest fresh shoot weight (5.72 g $plant^{-1}$) when compared to all of the other interactions. The significant ($P<0.01$) differences were observed among only bean cultivar x AMF species interaction for dry shoot weight [Table 2]. The Terzibaba cv x control AMF had the highest dry shoot weight (0.55 g $plant^{-1}$), while Sehirali cv x Gi had the lowest dry shoot weight (0.32 g $plant^{-1}$).

Similar to the fresh shoot weight, the significant ($P<0.01$) differences were observed among bean cultivars, AMF species and bean cultivar x AMF species interaction for fresh root weight [Table 1]. While Seker cv had the highest fresh root weight (1.43 g $plant^{-1}$), Sehirali cv had the lowest fresh root weight (0.67 g $plant^{-1}$). While Gm had the highest fresh root weight (1.45 g $plant^{-1}$), Gf had the lowest fresh root weight (0.95 g $plant^{-1}$). Seker cv x Gm had the highest fresh root weight (1.93 g $plant^{-1}$) when compared to all of the other interactions. The significant ($P<0.01$) differences were observed among bean cultivar and bean cultivar x AMF species interaction for dry root weight [Table 1]. While Terzibaba cv had the highest dry root weight (0.13 g $plant^{-1}$), Sehirali cv had the lowest dry root weight (0.08 g $plant^{-1}$). Similar to the dry shoot weight data, Terzibaba cv x control AMF had the highest dry root weight (0.16 g $plant^{-1}$), while Sehirali cv x Gi had the lowest dry root weight (0.06 g $plant^{-1}$).

The significant differences were observed among bean cultivars ($P<0.01$), AMF species($P<0.05$) for shoot height [Table 2]. While Onceler cv had the highest shoot height (16.95 cm), Sehirali cv had the lowest shoot height (13.25 cm). While Gi had the highest shoot height (16.34 cm), Gm had the lowest shoot height (14.45 cm).

The significant differences were observed among bean cultivars ($P<0.01$), AMF species ($P<0.05$) for root length [Table 2]. While Terzibaba cv had the highest root length (13.44 cm), Sehirali cv had the lowest root length (11.31 cm). While the control AMF treatment had the highest root length (12.84 cm), Gf had the lowest root length (11.86 cm).

The significant ($P<0.01$) differences were observed among bean cultivars, AMF species and bean cultivar x AMF species interaction for shoot diameter [Table 3]. While Onceler cv had the highest shoot diameter (4.31 mm), Terzibaba cv had the lowest shoot diameter (3.49 mm). While Gi had the highest shoot diameter (3.97 mm), Gm had the lowest shoot diameter (3.73 mm). The Onceler cv x Gi had the highest shoot diameter (4.91 mm) when compared to all of the other interactions.

The significant ($P<0.01$) differences were observed among bean cultivars, AMF species and bean cultivar x AMF species interaction for leaf number [Table 3]. While Seker cv had the highest leaf number (8.08), Onceler cv had the lowest leaf number (5.52). While Gm had the highest leaf number (7.30), Gi had the lowest leaf number (6.70). The Seker cv x Gi had the highest leaf number (9.03) when compared to all of the other interactions.

The significant ($P<0.01$) differences were observed among bean cultivars and bean cultivar x AMF species interaction for leaf area [Table 3]. While Terzibaba cv had the highest leaf area (157.74 cm^2), Seker cv had the lowest leaf area (121.73 cm^2). The Terzibaba cv x Gf had the highest leaf area (185.53 cm^2) when compared to all of the other interactions.

Plant Nutrient Contents

Cultivars, AMF species and cultivar x AMF species interaction had significant ($P<0.01$) effects on N contents of bean shoots [Table 4]. While Sehirali cv had the highest shoot N content (5.41 %), Seker cv had the lowest shoot N content (4.62 %). While Gm had the highest shoot N content (5.59 %), the control AMF application had the lowest shoot N content (4.48 %). The Sehirali cv x Gm had the highest shoot N content (7.61 %) when compared to all of the other interactions. Due to the insufficient sample amounts root N contents were not determined.

The shoot P contents of bean seedlings were significantly ($P<0.01$) affected from AMF species and cultivar x AMF species interaction [Table 5]. While Gm had the highest shoot P content (0.99 %), the control AMF application had the lowest shoot P content (0.77 %). The Terzibaba cv x Gm had the highest shoot P content (1.11 %) when compared to all of the other interactions. There were only significant differences ($P<0.01$) among AMF species for the root P contents [Table 5]. While Gi had the highest root P content (1.11 %), the control AMF application had the lowest root P content (0.84 %).

There were only significant differences ($P<0.01$) among AMF species for the shoot K contents [Table 6]. While Gi had the highest shoot K content (10.05 %), the control AMF application had the lowest shoot K content (7.43 %). Cultivars and AMF species had significant ($P<0.01$) effects on K contents of bean roots [Table 6]. While Terzibaba cv had the highest root K content (5.27 %), Onceler cv had the lowest root K content (4.27 %). While Gf had the highest root K content (5.24 %), Gi had the lowest root K content (4.36 %).

There were only significant differences ($P<0.05$) among AMF species for the root Ca contents [Table 7]. While Terzibab cv had the highest root Ca content (3.01 %), Onceler cv had the lowest root Ca content (2.35 %).

There were no significant differences among the treatments for the root and shoot Mg contents [Table 8]. There were no significant differences among the treatments for the shoot Fe contents, but the root Fe contents of bean seedlings were significantly affected from AMF species ($P<0.01$), bean cultivars ($P<0.05$), and cultivar x AMF species interaction ($P<0.01$) [Table 9]. While Gi had the highest root Fe content (6.71 $mg^{-1}kg$), the control AMF application had the lowest root Fe content (5.50 $mg^{-1}kg$). While Onceler cv had the highest root Fe content (6.20 $mg^{-1}kg$), Sehirali cv had the lowest root Fe content (5.52 $mg^{-1}kg$). The Sehirali cv x Gi had the highest root Fe content (7.27 $mg^{-1}kg$) when compared to all of the other interactions.

The shoot Cu contents of bean seedlings were significantly ($P<0.01$) affected from AMF species and bean cultivars [Table 10]. While Gm had the highest shoot Cu content (14.65 $mg^{-1}kg$), the control AMF application had the lowest shoot Cu content (10.40 $mg^{-1}kg$). While Onceler cv had the highest shoot Cu content (13.96 $mg^{-1}kg$), Sehirali cv had the lowest shoot Cu content (11.08 $mg^{-1}kg$). The root Cu contents of bean seedlings were also significantly affected from AMF species ($P<0.01$) and bean cultivars ($P<0.05$) [Table 10]. While Gf had the highest root Cu content (32.28 $mg^{-1}kg$), the control AMF application had the lowest root Cu content (26.17 $mg^{-1}kg$). While Sehirali cv had the highest root Cu content (32.08 $mg^{-1}kg$), Seker cv had the lowest root Cu content (28.05 $mg^{-1}kg$). TheTerzibaba cv x Gm and Sehirali cv x Gf had the highest root Cu contents (35.88 and 35.70 $mg^{-1}kg$, respectively) when compared to all of the other interactions.

The shoot Mn contents of bean seedlings were only significantly ($P<0.01$) affected from AMF species [Table 11]. While Gi had the highest shoot Mn content (65.46 $mg^{-1}kg$), the control AMF application had the lowest shoot Mn content (52.55 $mg^{-1}kg$). The root Mn contents of bean seedlings were significantly affected from AMF species ($P<0.01$) and bean cultivars ($P<0.05$) [Table 11]. While Gi had the highest root Mn content (174.08 $mg^{-1}kg$), the control AMF application had the lowest root Cu content (138.41 $mg^{-1}kg$). While Sehirali cv had the highest root Mn content (168.00 $mg^{-1}kg$), Terzibaba cv had the lowest root Mn content (147.38 $mg^{-1}kg$). The Sehirali cv x Gi had the highest root Mn content (221.47 $mg^{-1}kg$) when compared to all of the other interactions.

There were no significant differences among the treatments for the shoot Zn contents, but the root Zn contents of bean seedlings were significantly ($P<0.01$) affected from AMF species and bean cultivars [Table 12]. While Gf had the highest root Zn content (37.20 $mg^{-1}kg$), the control AMF application had the lowest root Zn content (30.41 $mg^{-1}kg$). While Seker cv had the highest root Zn content (38.90 $mg^{-1}kg$), Terzibaba cv had the lowest root Zn content (30.48 $mg^{-1}kg$).

AMF Colonization

The extent of root colonization varied significantly ($P<0.01$) among the bean cultivars, AMF species and cultivar-AMF combinations tested [Table 13]. The colonization rates (33%) of Gm and Gf were higher than that of Gi (24 %). The colonization rates of Seker (35%) and Sehirali (33%) bean cultivars and Gf were the highest, while the colonization rates of Onceler bean cultivar was the lowest (23 %). The Sehirali cv x Gf, the Seker cv x Gf and the Seker cv x Gm combinations had the highest colonization rates.

Conclusions

AMF are well known to have significant positive effects on bean and many other crops grown under various a/biotic stress conditions. However, several studies have been demonstrating that genetic differences in plant responses to AMF are widespread, regardless of crop (Declerck et al., 1995; Parke & Kaeppler, 2000; Linderman & Davis, 2004; Sensoy et al. 2007). The present study aimed to evaluate the responsiveness of four different bean cultivars to inoculation by three different AMF under salty seedling growing conditions. There were generally positive effects of AMF on the development of bean seedlings. Among the bean cultivars, Onceler and Terzibaba, and among the AMF species, *G. mosseae*, had the best results for plant growth. *G. mosseae* was followed by *G. intraradices*. On the other hand, there were significant variation among the results of cultivar-AMF combinations tested for most of the traits. Mycorrhizal dependency varies among plant species and cultivars; and this dependency was influenced by the genetic structure (Ortas & Akpınar, 2004). In the symbiotic relation, AMF alleviate certain nutrient deficiencies in plants by increasing nutrient uptake (Demir, 2004;Ortas & Akpınar 2006; Sensoy et al., 2007; Sharifi et al., 2007; Turkmen et al., 2008). The results of the presents study are in line with the literature. AMF especially supply P and Zn to the plants (Ortas & Akpınar, 2006). In the present study, P and Zn contents obtained from these three AMF species were generally higher than those of the control treatment. Moreover, Cu and Mn contents obtained from these three AMF species were also in general higher than those of the control treatment. The potassium (K) is an important mineral in salt tolerance mechanism (Gama at al., 2007); the more K/Na ratio, the higher tolerance to salt in the plants (Erdal et al., 2000; Türkmen et al., 2000). In the present study, the shoot K contents obtained from these three AMF species were significantly higher than that of the control treatment. In overall, it can be said that the AMF applications had generally positive effects on the plant growth and nutrient intake in the bean seedlings. In conclusion, as seen in the example of bean demonstrated in the present study, AMF might improve plant growth traits in vegetable species. However, considering the wide variety of responses from different bean cultivars to AMFs, as demonstrated in this and other studies, appropriate cultivar-AMF combinations need to be identified in order to derive the greatest benefit from symbiosis.

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Cultivar/AMF	Shoot Fresh Weigth, g plant^{-1}					Root Fresh Weigth, g plant^{-1}					Root Dry Weigth, g plant^{-1}				
	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean
Onceler	4.63 b-d**	5.47 ab	5.55 ab	4.67 b-d	5.08 A**	1.15 cd**	1.31 cd	1.45 cd	1.22 cd	1.28 A**	0.10 b-e**	0.11 b-d	0.10 b-e	0.09 c-e	0.10 BC**
Terzibaba	5.02 a-c	5.72 a	4.36 cd	4.34 cd	4.86 A	1.37 cd	1.86 ab	1.22 cd	1.13 cd	1.40 A	0.16 a	0.14 ab	0.11 b-d	0.11 b-d	0.13 A
Sehirali	4.72 a-c	4.11 cd	2.93 e	3.15 e	3.72 B	1.05 de	0.70 ef	0.35 f	0.57 f	0.67 B	0.10 b-e	0.08 de	0.06 e	0.10 b-e	0.08 C
Seker	5.13 a-c	5.13 a-c	4.94 de	3.71 de	4.70 A	1.52 bc	1.93 a	1.56 a-c	0.73 ef	1.43 A	0.09 c-e	0.13 a-c	0.14 ab	0.09 c-e	0.11 AB
Mean	4.86 AB**	5.10 A	4.44 B	3.96 C		1.25 B**	1.45 A	1.14 B	0.91 C		0.11	0.12	0.10	0.10	

**P < 0.01; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Table 1: Fresh shoot, fresh and dry root weigths of bean seedlings inoculated with diffirent AMF species.

Cultivar/AMF	Shoot Dry Weigth, g plant^{-1}					Shoot Heigth, cm					Root Length, cm				
	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean
Onceler	0.46 a-c**	0.49 ab	0.50 ab	0.41 b-d	0.46	16.66**	15.84	17.17	18.15	16.95 A**	12.95 a-c**	12.18 b-d	13.46 ab	12.28 b-d	12.72 B**
Terzibaba	0.55 a	0.50 ab	0.40 b-d	0.43 a-d	0.47	13.22	13.15	14.55	12.07	13.25 B	14.09 a	13.74 ab	12.94 a-c	13.00 a-c	13.44 A
Sehirali	0.50 ab	0.44 a-d	0.32 d	0.46 a-c	0.43	15.13	15.81	17.32	14.79	15.76 A	12.80 a-c	11.68 cd	9.75 e	10.99 de	11.31 C
Seker	0.35 cd	0.45 a-c	0.50 ab	0.40 b-d	0.43	18.32	13.01	16.34	17.47	16.28 A	11.53 cd	11.68 cd	13.51 ab	11.18 de	11.97 C
Mean	0.47	0.47	0.43	0.43		15.83 AB*	14.45 B	16.34 A	15.62 AB		12.84 A*	12.32 AB	12.41 AB	11.86 B	

*P < 0.05; **P < 0.01; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Table 2: Dry shoot weigth and shoot and root lengths of bean seedlings inoculated with diffirent AMF species

Cultivar/AMF	Stem Diameter, mm					Leaf Number					Leaf Area, cm^2				
	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean
Onceler	4.29 b**	3.98 bc	4.91 a	4.04 bc	4.31 A**	6.43 de**	5.94 ef	4.26 g	5.44 f	5.52 C**	166.22 ab**	145.31 b-e	136.80 b-f	112.80 ef	140.28 B**
Terzibaba	3.52 f-h	3.53 e-h	3.40 h	3.50f-h	3.49 C	7.66 bc	7.63 bc	7.10 cd	7.35 b-d	7.43 B	126.59 c-f	157.37 a-d	161.48 a-c	185.53 a	157.74 A
Sehirali	3.79 c-g	3.95 b-d	3.90 c-e	3.86 c-f	3.87 B	7.50 bc	7.47 bc	6.41 de	7.12 cd	7.12 B	153.28 a-d	131.13 b-f	123.47 d-f	135.89 b-f	135.94 BC
Seker	3.45 gh	3.47 gh	3.68 c-h	3.58 d-h	3.55 C	7.46 bc	8.16 b	9.03 a	7.67 bc	8.08 A	135.31 b-f	104.55 f	125.93 c-f	121.13d-f	121.73 C
Mean	3.76 B**	3.73 B	3.97 A	3.74 B		7.26 A**	7.30 A	6.70 B	6.89 AB		145.35	134.59	136.92	138.84	

**P < 0.01; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Table 3: Stem diameter, leaf number and leaf area of bean seedlings inoculated with diffirent AMF species.

Cultivar/AMF	Shoot N contents (%)				
	Control	Gm	Gi	Gf	Mean
Onceler	4.66 c-e**	5.08 bc	5.08 bc	5.09 bc	4.97 B**
Terzibaba	4.35 de	4.75 cd	4.77 cd	4.81 cd	4.66 BC
Sehirali	4.37 de	7.61 a	4.63 c-e	5.65 b	5.41 A
Seker	4.60 c-e	5.22 bc	4.06 e	4.60 c-e	4.62 C
Mean	4.48 C**	5.59 A	4.63 C	5.02 B	

**P < 0.01; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Table 4: Shoot N content of bean seedlings inoculated with diffirent AMF species.

Cultivar/AMF	P (%)									
	Shoot					Root				
	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean
Onceler	0.80 de**	0.93 bc	1.00 b	0.96 bc	0.92	0.78	1.04	1.07	0.80	0.92
Terzibaba	0.71 e	1.11 a	0.93 bc	1.00 b	0.93	1.00	1.09	1.23	0.99	1.07
Sehirali	0.79 de	0.91 bc	0.87 cd	0.99 b	0.89	0.71	1.10	1.25	0.81	0.95
Seker	0.78 de	1.01 b	0.91 bc	0.93 bc	0.91	0.81	1.16	1.00	0.89	0.96
Mean	0.77 C**	0.99 A	0.93 B	0.97 AB		0.84 B**	1.09 A	1.11 A	0.88 B	

**P < 0.01; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Tablo 5: Shoot and root P contents of bean seedlings inoculated with diffirent AMF species.

	K (%)									
	Shoot					Root				
Cultivar/AMF	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean
Onceler	6.78	9.01	10.46	7.36	8.11	4.37 cd**	4.28 cd	3.86 de	4.56 cd	4.27 B**
Terzibaba	8.89	8.61	11.52	8.64	9.47	5.10 c	5.99 b	3.12 e	7.04 a	5.27 A
Sehirali	7.40	8.62	8.86	10.58	8.88	4.45 cd	4.82 cd	3.92 dc	4.60 cd	4.52 B
Seker	6.39	11.02	9.41	10.22	9.26	4.42 cd	4.77 cd	6.32 ab	4.61 cd	5.03 A
Mean	7.43 B**	9.29 A	10.05 A	9.13 A		4.59 BC**	4.90 AB	4.36 C	5.24 A	

**P < 0.01; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Tablo 6: Shoot and root K contents of bean seedlings inoculated with diffirent AMF species.

	Ca (%)									
	Shoot					Root				
Cultivar/AMF	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean
Onceler	2.61	3.67	3.57	4.40	3.56	2.38	2.39	2.35	2.26	2.35 B*
Terzibaba	3.85	3.35	3.57	3.97	3.71	3.57	3.55	2.45	2.60	3.01 A
Sehirali	4.88	4.00	3.74	3.14	3.93	2.15	2.62	2.73	3.18	2.62 AB
Seker	3.08	4.34	2.27	3.45	3.29	2.45	2.34	2.44	2.73	2.49 AB
Mean	3.64	3.82	3.32	3.76		2.63	2.67	2.46	2.66	

*P < 0.05; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Table 7: Shoot and root Ca contents of bean seedlings inoculated with diffirent AMF species.

	Mg ($mg^{-1}kg$)									
	Shoot					Root				
Cultivar/AMF	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean
Onceler	1.29	1.76	1.63	1.63	1.57	1.35	1.48	1.56	1.37	1.44
Terzibaba	1.42	1.34	1.55	1.51	1.46	1.77	1.44	1.26	1.61	1.52
Sehirali	1.60	1.53	1.50	1.46	1.52	1.52	1.53	1.19	1.34	1.43
Seker	1.38	1.68	1.33	1.48	1.47	1.48	1.44	1.51	1.56	1.49
Mena	1.43	1.59	1.49	1.52		1.53	1.47	1.40	1.48	

Glomus mosseae (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Tablo 8: Shoot and root Mg contents of bean seedlings inoculated with diffirent AMF species.

	Fe ($mg^{-1}kg$)									
	Shoot					Root				
Cultivar/AMF	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean
Onceler	1.61	2.09	2.29	1.88	1.92	5.76 c-e**	6.60 a-d	6.54 a-d	5.90 b-e	6.20 A*
Terzibaba	2.04	1.61	2.04	1.61	1.84	6.90 a-c	6.61 a-d	7.17 ab	3.56 g	6.02 AB
Sehirali	1.81	1.78	1.83	1.83	1.81	4.14 fg	5.49 de	7.27 a	6.25 a-e	5.52 B
Seker	1.68	1.35	1.69	1.84	1.64	5.20 ef	5.48 de	6.14 a-e	6.87 a-c	5.92 AB
Mean	1.79	1.74	1.93	1.79		5.50 B**	6.00 B	6.71 A	5.60 B	

*P < 0.05; **P < 0.01; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Table 9: Shoot and root Fe contents of bean seedlings inoculated with diffirent AMF species.

Cu ($mg^{-1}kg$)										
	Shoot					Root				
Cultivar/AMF	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean
Onceler	10.24	18.73	17.45	11.17	13.96 A**	25.58 de**	24.40 e	32.13 a-d	34.32 a-c	29.11 AB*
Terzibaba	13.29	15.55	13.25	12.67	13.57 A	24.21 e	35.88 a	17.56 f	31.54 a-e	26.72 B
Sehirali	9.06	10.76	12.35	12.07	11.08 B	27.23 c-e	34.79 ab	30.96 a-e	35.70 a	32.08 A
Seker	8.55	12.19	11.86	12.21	11.20 B	27.69 b-e	26.73 de	29.34 a-e	28.43 a-e	28.05 B
Mean	10.40 C**	14.65 A	13.30 AB	12.02 BC		26.17 C**	30.09 AB	27.00 BC	32.28 A	

*P < 0.05; **P < 0.01; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Table 10: Shoot and root Cu contents of bean seedlings inoculated with diffirent AMF species.

Mn ($mg^{-1}kg$)										
	Shoot					Root				
Cultivar/AMF	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean
Onceler	50.20	61.57	63.91	60.72	58.41	154.67 cd**	166.72 cd	168.54 cd	161.89 cd	162.95 AB*
Terzibaba	53.56	63.86	68.53	57.88	60.76	133.57 de	178.67 bc	172.92 cd	112.18 e	147.38 B
Sehirali	54.97	60.14	66.65	52.45	58.74	116.25 e	159.74 cd	221.47 a	212.36 ab	168.00 A
Seker	49.60	61.46	60.84	64.71	59.08	149.17 c-e	156.63 cd	157.07 cd	179.80 bc	160.67 AB
Mean	52.55 C**	61.74 AB	65.46 A	58.49 B		138.41 C**	164.56 A	174.08 A	163.50 A	

*P < 0.05; **P < 0.01; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Table 11: Shoot and root Mn contents of bean seedlings inoculated with diffirent AMF species.

Zn ($mg^{-1}kg$)										
	Shoot					Root				
Cultivar/AMF	Control	Gm	Gi	Gf	Mean	Control	Gm	Gi	Gf	Mean
Onceler	21.88	28.19	20.76	24.47	24.26	34.21	38.17	34.51	40.58	36.87 A**
Terzibaba	23.91	20.09	26.21	22.31	23.33	24.79	36.02	29.23	32.53	30.48 B
Sehirali	23.95	25.01	23.84	23.62	24.05	26.90	35.31	36.45	40.63	34.13 AB
Seker	23.67	20.27	20.10	22.03	21.52	35.75	38.37	45.58	35.91	38.90 A
Mean	23.33	23.76	23.23	23.18		30.41 B**	37.03 A	36.65 A	37.20 A	

**P < 0.01; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Table 12: Shoot and root Zn contents of bean seedlings inoculated with diffirent AMF species.

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AMF colonisation rate (%)				
Cultivar/AMF	Gm	Gi	Gf	Mean
Onceler	35 b**	15 d	22 c	23 C**
Terzibaba	31 b	29 bc	26 bc	29 B
Sehirali	29 bc	28 bc	43 a	33 A
Seker	40 a	25 bc	40 a	35 A
Mean	33 A**	24 B	33 A	

**P < 0.01; *Glomus mosseae* (Gm), *G. intraradices* (Gi) and *G. fasciculatum* (Gf)

Table 13: AMF colonisation of bean seedlings inoculated with diffirent AMF species