The Effect of Microbial Fertilizers on the Mineral Content of Some Cowpea (*Vigna unguiculuta* L. *Walp*.) Varieties

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Abstract: Cowpea plant and other legumes are known as important protein sources, but their effect on mineral content in human nutrition is less known. Legumes are of great importance in developing countries where access to animal protein sources is difficult. Cowpea grains and leaves are a source of carbohydrates, proteins, fats, ß-carotene and vitamins B and C necessary for a healthy diet. This study was conducted to investigate the mineral matter contents of different foliar applications of microbial fertilizer sources to some cowpea (*Vigna unguiculata* L. Walp) cultivars (Akkız 86, Karagöz 86). The research was conducted in the experimental field of Erciyes University Agricultural Research and Application Center in the 2022 growing season. Grains obtained from Akkız 86 and Karagöz 86 cowpea cultivars were used as plant material. In the study, the mineral matter contents of cowpea grains were examined and the mean values obtained from the cultivar*bacteria interaction were examined; boron 17.457-14.200 mg/kg, calcium 1127.27-859.86 mg/kg, copper 13.963-10.330 mg/kg, iron 42.590-25.923 mg/kg, potassium 8104.8-6150.9 mg/kg, magnesium 1811.29-1260.25 mg/kg, manganese 18.493-12.520 mg/kg, phosphorus 5258.68-3621.19 mg/kg, sulfur 1091.97-3621.19 mg/kg and zinc 56.53-36.887 mg/kg. As a result, it was determined that Omed+4 and Imed microbial fertilizer sources caused significant decreases in the mineral content of cowpea seed, especially in mineral content other than iron element.

Keywords: Cowpea, Microbial fertilizer sources, Mineral matter, PCA

Bazı Börülce(*Vigna unguiculata* L. *Walp*.) Çeşitlerine Uygulanan Mikrobiyal Gübrelerin Mineral Madde İçeriklerine Etkisi

Öz: *Börülce bitkisi ve diğer baklagiller önemli protein kaynağı olarak bilinmekte, ancak insan beslenmesinde mineral içeriklerine etkisi daha az bilinmektedir. Hayvansal protein kaynaklarına ulaşımın zor olduğu gelişmekte olan ülkelerde baklagiller büyük bir önem arz etmektedir. Börülce tane ve yaprakları sağlıklı bir beslenme için gerekli olan karbonhidratlar, proteinler, yağlar, ß-karoten ile B ve C vitaminlerinin kaynağıdır. Bu çalışma, bazı börülce (Vigna unguiculata L. Walp) çeşitlerine (Akkız 86, Karagöz 86) yapraktan farklı mikrobiyal gübre uygulamalarının mineral madde içeriklerini incelemek amacı ile yapılmıştır. Araştırma 2022 yetiştirme sezonunda ….. Üniversitesi Tarımsal Araştırma ve Uygulama Merkezine ait deneme arazisinde yürütülmüştür. Denemede Akkız 86 ve Karagöz 86 börülce çeşitlerinden elde edilen taneler bitki materyali olarak kullanılmıştır. Araştırmada börülce tanesinde mineral madde içerikleri incelenmiş ve çeşit*bakteri interaksiyonundan elde edilen ortalama değerler incelendiğinde bor 17.457-14.200 mg/kg, kalsiyum 1127.27-859.86 mg/kg, bakır 13.963-10.330 mg/kg, demir 42.590-25.923 mg/kg, potasyum 8104.8-6150.9 mg/kg, magnezyum 1811.29-1260.25 mg/kg, mangan 18.493-12.520 mg/kg, fosfor 5258.68-3621.19 mg/kg, kükürt 1091.97-3621.19 mg/kg ve çinko 56.53-36.887 mg/kg arasında değişim göstermiştir. Sonuç olarak , Omed+4 ve İmed mikrobiyal gübrelerinin börülce tanesindeki mineral madde içeriğinde, özellikle demir elementi dışındaki mineral madde içeriklerinde önemli azalmalara neden olduğu belirlenmiştir.*

***Anahtar kelimeler:* Börülce, Mikrobiyal gübre kaynakları, Mineral madde, PCA**

INTRODUCTION

Edible grain legumes, which are of great importance in the world and in Türkiye, constitute the main source of vegetable proteins in nutrition and constitute 22% of vegetable proteins and 7% of carbohydrates used in human nutrition (Bolat et al., 2017). Edible grain legumes in the *Fabaceae* family are the largest family among flowering plants with approximately 700 genera and 18 thousand species. Cowpea (*Vigna unguiculata* L.*Walp*) is a member of the *Fabaceae* family and is an annual, diploid and self-fertilized plant (Sepetoğlu, 2006). In Türkiye, cowpea comes after peas in terms of cultivation area and production amount among edible legumes (TÜİK, 2024). The dry grains of cowpea have high nutritional content in terms of human nutrition. Protein, oil, mineral matter and fiber ratios vary according to the variety and growing conditions.

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Protein rate varies between 20-25%, fat rate between 1.3-1.5% and fiber rate between 5.1-5.8% (Tshovhote et al., 2003). The fact that cowpea is a very rich plant in terms of both protein and carbohydrate content is important for human nutrition. Cowpea plant also contains folic acid and microelements.

In general, nitrogen and phosphorus fertilizers are used more than other fertilizers in crop production. Besides the fact that nitrogen is one of the absolutely necessary elements for plant development, nitrogen deficiency is quite high in our country. The amount of nitrogen needed by plants is tried to be given to plants by fertilization. However, as a result of the increase in the use and cost of fertilizers, it has become important to fix the free nitrogen in the air and soil by using legumes and transform it into a form that plants can use. Bacteria are inoculated into the soil and accelerate the binding process of free nitrogen. Microbial fertilizer sources containing bacteria increase the uptake of plant nutrients in the soil and plant growth (Kashem and Singh, 2002). The important properties of microbial fertilizer sources, which have a mutualistic life with plant roots, include binding free nitrogen in the atmosphere that plants cannot use, ensuring the dissolution of organic phosphorus and promoting the production of some secondary metabolites (İmriz et al., 2014).

The use of biological fertilizers is becoming increasingly important for sustainable agriculture. The use of biological fertilizers has accelerated the uptake of plant nutrients by improving soil structure and increasing symbiotic life activities (Altunlu et al., 2019). Microorganisms such as algae, bacteria and fungi are used as microbial fertilizer sources (Pişkin, 2021). In this study, different microbial fertilizer sources were applied to cowpea plant cultivated in Kayseri ecological conditions and it was aimed to examine their effects on the mineral matter content in cowpea grains.

MATERIAL and METHODS

In this study, cowpea grains obtained from the research carried out in 2022 in the trial plots of Erciyes University Agricultural Research and Application Center were used according to the split-plot trial design in randomized blocks with 3 replications. Commercial fertilizers named Omed, İmed, Omed+4 and Çim+14-3, which have nitrogen fixing and phosphorus solubilizing effects, were used as microbial fertilizer sources. While Imed contains *Bacillus nitratireducens* strains isolated from our country's soil, Omed is a liquid microbial fertilizer source containing *Bacillus thuringiensis, Bacillus simplex, Bacillus amyloliquefaciens* strains. In the study, cowpea grains were ground and 0.5 g of ground sample was exposed to 10 ml of nitric acid + perchloric acid mixture and the samples were burned. Mineral composition readings of macro elements (Ca, K, Mg, P, S) and micro elements (B, Cu, Zn, Mn, Fe) were determined using Agilent 5800 VDV model ICP- OES (Özaktan et al. 2025). The data obtained as a result of the study were subjected to analysis of variance with the "JMP 17.0 Pro" statistical package program. If the difference between the groups was significant, Tukey multiple comparison test was performed. Scatterplot, correlation and biplot multiple comparison analyzes were performed on the data obtained (Özaktan and Doymaz, 2022).

RESULTS AND DISCUSSION

The results of analysis of variance for boron, calcium, copper, iron and potassium content values of microbial fertilizer sources applied to different cowpea cultivars and Tukey results for the averages are given in Table 1; the results of analysis of variance for magnesium, manganese, phosphorus, sulfur and zinc content values and Tukey results for the averages are given in Table 2. Among the sources of variation, the effect of bacteria application on mineral matter contents other than potassium was found statistically significant, while the effect of cultivars on boron, copper, magnesium, manganese and phosphorus content values was found statistically significant ($p<0.05$). When the mean values obtained from cultivar*bacteria interaction were analyzed, boron 17.457-14.200 mg/kg, calcium 1127.27-859.86 mg/kg, copper 13.963-10.330 mg/kg, iron 42.590-25.923 mg/kg, potassium 8104.8-6150.9 mg/kg, magnesium 1811.29-1260.25 mg/kg, manganese 18.493-12.520 mg/kg, phosphorus 5258.68-3621.19 mg/kg, sulfur 1091.97-3621.19 mg/kg and zinc 56.53-36.887 mg/kg (Table 1;2).

When the overall average of the bacteria was analyzed, the effect of the bacteria on the elements other than potassium was found to be statistically significant at $p\leq0.01$ level among the elements in Table 1. Omed and Çim+14-3 microbial fertilizer sources caused a significant increase in boron and copper contents, while control, Imed and Omed+4 treatments caused a significant decrease in the contents of these elements. When the effects of microbial fertilizer sources on calcium content were analyzed, the highest value was obtained from the control group with 1101.85 mg/kg and it was in the same group with Çim+14-3 application (Table 1). While İmed and Omed+4 treatments provided a significant increase in iron element, they caused significant decreases in other mineral matter contents (Table 1;2).

Table 1. Mean (mg/kg) B, Ca, Cu, Fe and K contents of some cowpea cultivars of different microbial fertilizer sources and Tukey groups

		Boron (B)	Calcium (Ca)	Copper (Cu)	Iron (Fe)	Potassium (K)
Akkız 86	Control	16.57abc	1105.84ab	11.18cd	26.36d	6514.00
	Çim+14-3	17.46a	1127.27a	12.4bc	31.04cd	8104.82
	Omed	17.23ab	922.60de	10.61d	33.72bc	6727.31
	İmed	16.51abc	951.32cde	10.60d	36.77abc	6552.13
	Omed+4	14.60d	954.01b-e	10.33d	42.59a	6273.01
Karagöz 86	Control	15.13cd	1097.87abc	11.59cd	36.52abc	6854.48
	Çim+14-3	17.36a	1026.01a-d	13.51ab	30.85cd	7749.11
	Omed	17.08ab	1078.03abc	13.96a	25.92d	7861.92
	İmed	14.20d	867.63e	10.59d	38.06ab	6150.92
	Omed+4	15.58bcd	859.86e	12.34bc	36.01bc	6690.86
General Average						
Bacteria	Control	15.85B	1101.85A	11.39B	31.44 B	6684.24
	Çim+14-3	17.41A	1076.64AB	12.96A	30.95 B	7926.97
	Omed	17.15A	1000.32BC	12.29A	29.82 B	7294.62
	İmed	15.36B	909.47CD	10.59B	37.07 A	6351.53
	Omed+4	15.09B	906.94D	11.33B	39.30 A	6481.94
Cultivar	Akkız 86	16.47 ***A***	1012.21	11.02 ***B***	33.96	6834.25
	Karagöz 86	15.87 ***B***	985.88	12.40 ***A***	33.47	7061.46
Sum of Squares						
Sources of Variation	Block	2.85	7252.91	0.73	1.91	786697
	Cultivar (A)	2.73*	5198.73	14.19*	1.75	387160
	Error1	0.27	2270.62	0.08	0.83	2548299
	Bacteria (B)	26.58**	198595**	20.27**	422.65**	10300000
	AxB	9.86*	70314.5*	10.85**	315.02**	2410906
	Error2	5.54	42517.53	3.33	78.14	21624612
	General	47.84	326149.4	49.44	820.31	38084186

Table 2. Means (mg/kg) and Tukey groups of Mg, Mn, P, S and Zn contents of some cowpea cultivars of different microbial fertilizer sources

		Magnesium (Mg)	Manganese (Mn)	Phosphorus (P)	Sulfur (S)	Zinc (Zn)
Akkız 86	Control	1536.69	15.6b	4256.82	963.26	48.19
	Çim+14-3	1488.29	15.517bc	3910.75	989.87	51.72
	Omed	1587.51	13.637de	4453.61	1010.62	47.22
	İmed	1260.25	12.53e	3621.19	969.87	36.89
	Omed+4	1398.72	12.52e	4003.87	867.99	40.76
Karagöz 86	Control	1780.63	18.49a	5086.42	1053.29	53.29
	Çim+14-3	1682.11	14.45cd	4480.08	953.08	53.05
	Omed	1811.29	15.70b	5258.68	1091.97	56.53
	İmed	1493.76	14.45cd	4501.11	935.39	43.89
	Omed+4	1559.97	13.23e	4315.11	892.05	44.00
General Average						
Bacteria	Control	1658.66 AB	17.05 A	4671.62A	1008.28AB	50.74AB
	Çim+14-3	1585.21 B	14.98 B	4195.42B	971.47AB	52.39A
	Omed	1699.4 A	14.67 B	4856.14A	1051.3A	51.87A
	İmed	1377.01 D	13.49 C	4061.15B	952.63BC	40.39C
	Omed+4	1479.35 C	12.87 C	4159.49B	880.02C	42.38BC
Cultivar	Akkız 86	1454.29***B***	13.96***B***	4049.25***B***	960.32	44.96
	Karagöz 86	1665.55***A***	15.27***A***	4728,28***A***	985.16	50.15
Sum of Squares						
Sources of Variation	Block	3980.59	0.27	117538	2529.57	7.06
	Cultivar (A)	334729*	12.78*	3458147*	4624.71	202.54
	Error1	909.154	0.49	225486	1004.31	150.98
	Bacteria (B)	418759**	62.13**	2974380**	98622.1**	781.49*
	AxB	6787.59	14.18**	339324	22144.3	58.58
	Error2	34056.48	2.33	627620.2	33867.85	906.60
	General	799221.5	92.19	7742495	162792.9	2107.25

In addition, Çim+14-3 and Omed microbial fertilizer sources significantly increased copper accumulation in grain compared to control, Imed and Omed+4 microbial fertilizer sources (Table 1). When the elements in Table 2 were analyzed, it was found that the effect of microbial fertilizer sources on other mineral matter contents except zinc was statistically significant at ($p<0.01$). Imed and Omed+4 treatments significantly decreased the calcium, magnesium, manganese, phosphorus, sulfur and zinc values in the grain compared to the control (Table 1;2).

When the general averages of the cultivars were analyzed, boron and calcium contents in the grains of Akkız 86 cultivar had the highest value with 16.473 mg/kg and 1012.21 mg/kg, respectively. Karagöz 86 cultivar had the highest values in copper (12.399 mg/kg), magnesium (1665.56 mg/kg), manganese (15.266 mg/kg) and phosphorus (4728.28 mg/kg) elements and these differences were found statistically significant (Table 1;2).

When the findings obtained were compared with the literature, they were in parallel with the results reported by many researchers such as Yürürdurmaz (2022), Gondwe et al. (2019), Gerrano et al. (2019), Owolabi et al. (2012), Boukar et al. (2011) among the studies on cowpea; while they differed from the results reported by researchers such as Biema et al. (2020), Mamiro et al. (2011) (except Ca), Oke et al. (1994) (except P).

The scatterplot, fit line and correlation analysis outputs and values of mineral matter contents of cowpea grain of different microbial fertilizer sources treatments are given in Figure 1, while the results of biplot analysis are given in Figure 2. When the scatterplots, fit lines and red and blue colored correlation circles consisting of the relationships between the mineral matter contents obtained as a result of the applications (Figure 1), the highest positive correlation in mineral matter contents is r=0. 90** between magnesium and phosphorus, r=0.78** between potassium and zinc, r=0.68** between magnesium and manganese, r=0.67** between magnesium and zinc, r=0.65** between calcium and manganese and r=0.62** between copper and magnesium. On the other hand, there were negative correlations between boron and iron r=-0.65**, copper and iron r=-0.60** and calcium and iron r=-0.55**. Among the microbial fertilizer sources used in cowpea grain, Omed+4 and Imed played an important role in increasing iron content, while Omed played an important role in increasing zinc and sulfur contents (Figure 2).

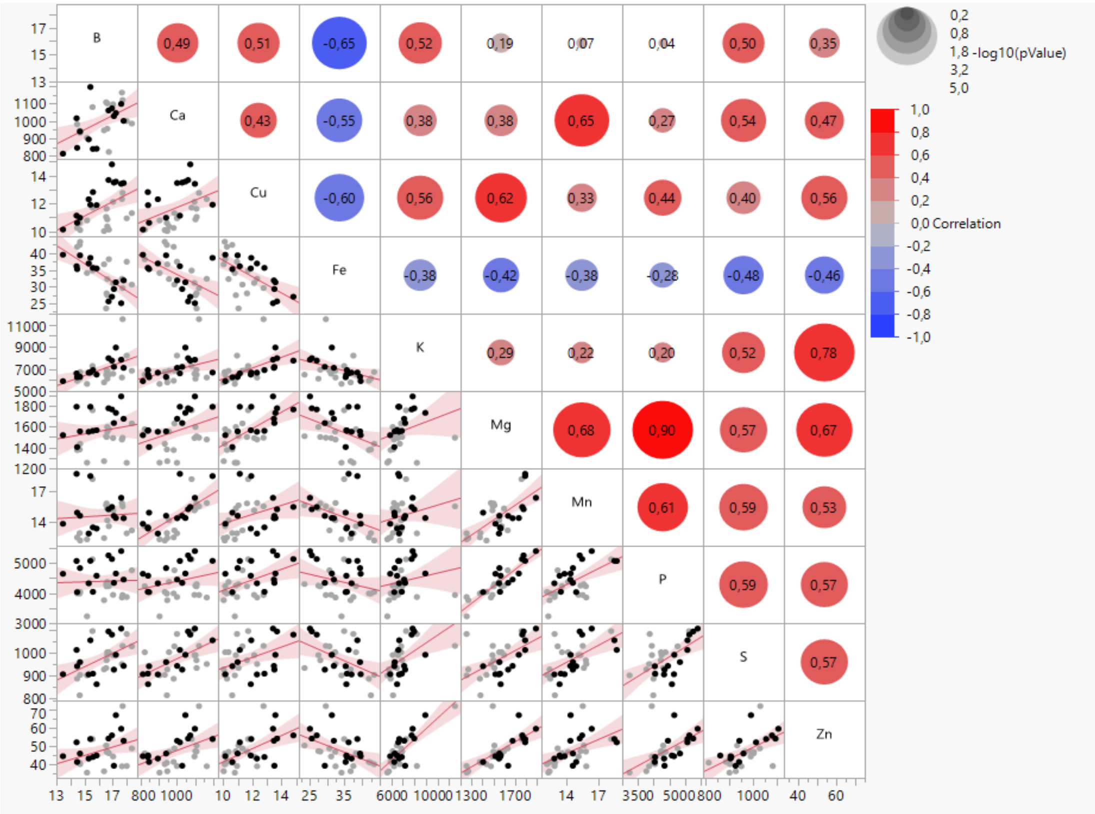
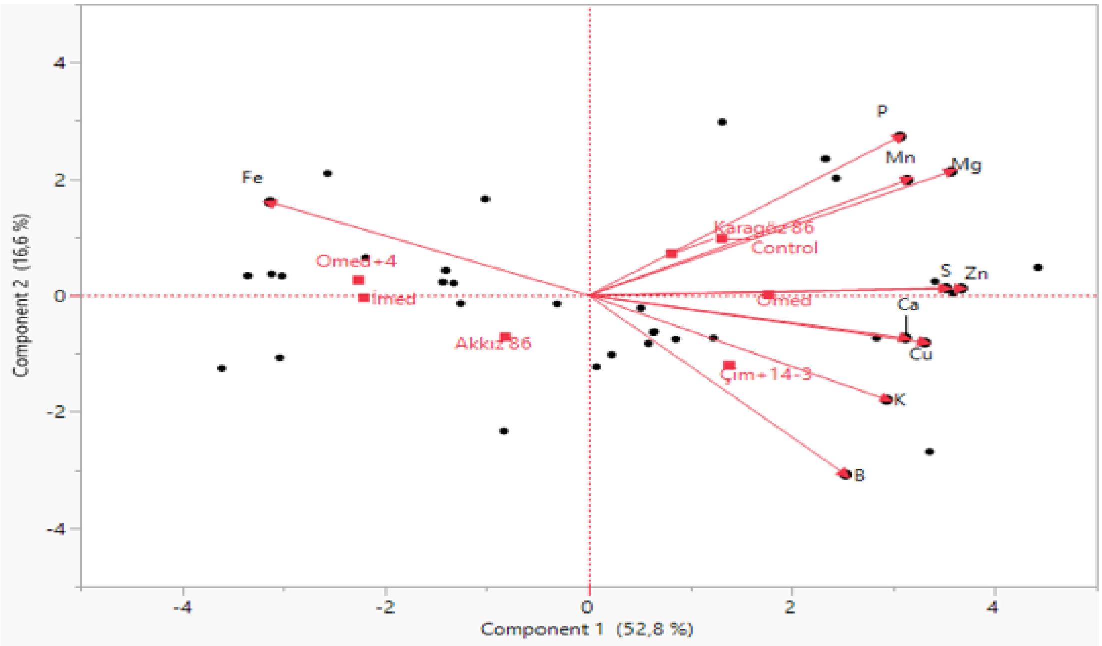


Figure 1. Scatterplot and correlation analysis on the parameters studied in some cowpea cultivars treated with different microbial fertilizer sources

When the biplot analysis on the mineral substances examined in some cowpea cultivars where different microbial fertilizer sources were applied, ten independent principal component axes were formed, and the first three principal components corresponded to 78.921% of the total variation. The data obtained show that biplot analysis can be interpreted successfully (Özaktan and Doymaz, 2022). When the biplot analysis output was analyzed, it was revealed that boron, potassium, copper and calcium axes were in the same region and each of them had a positive relationship with each other when the angle between each other was observed (Figure 1;2). In addition, since the phosphorus, manganese and magnesium axes are clustered in a different region, a positive relationship was also formed between them. Considering the length and position of the axis formed by the iron element and the angle formed with the axes of the other elements, a negative correlation was recorded with boron (Figure 2). Yeken et al. (2018) reported a positive correlation between K and Zn (r=0.447; P<0.05), Ca and Mg (r=0.693; P<0.01); Yürürdurmaz (2022) reported that P 5.17-4.71 g/kg, K 13.03-13.89 g/kg, Ca 1.01-1.15 g/kg, Mg 1.74-1.90 g/kg, Fe 44.54-55.19 mg/kg, Mn 16.30-17.69 mg/kg, Zn 33.11-37.48 mg/kg and Cu 8.67-9.84 mg/kg. He also reported that phosphorus had a significant positive relationship with potassium, magnesium, zinc and copper elements, and copper had a significant positive relationship with potassium, calcium and magnesium. The results obtained are consistent with the literature.



Number	Eigenvalue	Percent	Cum Percent
1	5,280273	52,803	52,803
2	1,655026	16,550	69,353
3	0,956793	9,568	78,921
4	0,761429	7,614	86,535
5	0,548895	5,489	92,024
6	0,330002	3,300	95,324
7	0,220170	2,202	97,526
8	0,144523	1,445	98,971
9	0,067331	0,673	99,644
10	0,035557	0,356	100,000

Figure 2. Biplot analysis and values on the parameters studied in some cowpea cultivars treated with different microbial fertilizer sources

CONCLUSION

In this study in which the effect of microbial fertilizer sources applied to some cowpea cultivars on the mineral matter content in the grain was investigated, Omed+4 and İmed microbial fertilizer sources caused significant decreases in the mineral matter contents in the seed, especially in mineral matter contents except iron element. In addition, Çim+14-3 and Omed bacterial applications statistically increased copper accumulation in seed significantly compared to control, İmed and Omed+4 bacterial applications. Among the microbial fertilizer sources used, Omed+4 and İmed played an important role in increasing the iron content in the seed, while Omed played an important role in increasing the zinc and sulfur contents.

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