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Research Article

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The Effect of Different Mycorrhizal Fungi Inoculation and Biochar Application on the Growth of Broad Bean Plant and Carbon Sequestration under Different Irrigation Levels.

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ABSTRACT
The experiment was carried out in a total of 54 pots, with 3 replications according to the randomized plot trial design. In the experiment, broad bean (Vicia faba) plant seeds were planted as plant material. In the experiment, 3 irrigation levels were determined for restricted irrigation (50%, 75%, 100% of the field capacity), 3 levels were determined for mycorrhizal fungus (non-mycorrhizal, *G. mosseae* and indigenous mycorrhiza), and for biochar treatments, control and 1% biochar were implemented. As a result of the experiment, carbon analyzes of soil and plant samples were carried out. The data obtained in the study were determined to develop better at 100% irrigation level under the conditions of biochar and G. mosseae inoculation. Carbon and nitrogen values were higher in bean plants in pots inoculated with mycorrhiza and treated with biochar. These results imply that increased soil and plant performance under restricted irrigation conditions can result from the application of biochar and irrigation at level I100.
Keywords: Carbon, mycorrhiza, biochar, bean plant, water use efficiency

INTRODUCTION
The world population was 250 million in the 1000's, it increased to 6.1 billion in 2000 and it is expected to be 9.8 billion by 2050 (Kopittke et al., 2019). In response to population growth, the demand for food is expected to double, and the consumption of drinking water and agricultural irrigation water is expected to increase. In addition, the increasing world population day by day has a significant impact on soils ability to provide the amount of food necessary for human nutrition (Akşahin et al., 2019). As a renewable natural resource, water ranks first among the strategic resources in the world in the 21st century. In addition, increasing drought and very large water scarcity will make the sharing and management of water resources more problematic (Çakmak and Gökalp, 2013) Food security and water sustainability in arid and semi-arid regions are under threat due to rapid population growth, declining natural resources, and global climate change (Abdullah et al., 2022). In general, agricultural irrigation and production consume 70-75% of freshwater resources. It is extremely important to use the water used for agriculture in a more convenient and sustainable way. In light of this information, several plants depend on the correct management of water and soil in order to use the water more efficiently.
In order to maintain adequate water supply in the future for countries like Turkey, which are on the border of water scarcity, it is extremely important to activate the natural mechanisms of plants in the axis of water management and to correctly determine the existing natural plant mechanisms to plan plant production under moisture stress conditions, taking into account the soil-water-plant relationship. Many parameters should be considered in determining plant, water, and soil management. It is extremely important that some of these parameters be determined by the performance of the plants under limited irrigation conditions and to establish positive relations with soil microorganisms. Choosing plants known for their relationship with soil microorganisms is important for both saving water and providing a suitable environment for the plant.
The importance of water is not the only factor that the increase in carbon dioxide equivalent gases in the atmosphere has an impact on at the global scale. It is extremely important that part of these increasing changes arising from agriculture is brought back to agricultural lands. In light of this information, it is extremely important to investigate ways to add carbon to soils.
In addition to keeping water in the soil and keeping it ready for the plant, biochar, which provides a good plant nutrient for plants, is among the subjects that have been studied frequently recently. Lehmann (2009) defines biochar as a material produced by the pyrolysis of organic materials at relatively low temperatures (<700°C) with a limited amount of oxygen. The pyrolysis process, on the other hand, is defined as the thermo-chemical decomposition of organic matter at high temperatures in an oxygen-free environment.

Materials rich in carbon content obtained by heating very different and diverse biomass in an oxygen-free environment are defined as biochar. Biochar is also used differently from non-organic but charred material since it expresses a biological origin.

Known for their nitrogen fixation and significant mycorrhizal dependence within these relationships, broad bean crops can increase soil fertility and conserve water in the arid and semi-arid climatic regions of the Middle East. Due to the symbiotic relationship, the pod has a mechanism to use soil water efficiently.

Under stress conditions, rhizosphere unity, especially native mycorrhizae and plant roots, is significantly important for water uptake.

In light of this information, it was aimed to understand how the bean plant affects soil and plant carbon sequestration in the presence of mycorrhiza under limited irrigation conditions and biochar applications during the establishment of the experiment.

The hypothesis of the study is that mycorrhiza and biochar application under limited irrigation conditions will have a positive effect on the growth of the bean plant and will save irrigation water, and also that the carbon uptake of the plant will increase, and the amount of soil carbon retained in the soil will increase.

MATERIALS AND METHODS

The study was started on February 10, 2022, in the research greenhouses of Çukurova University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, and was completed on April 16, 2020.

The effect of different mycorrhizal fungi inoculation (control, indigenous and selected inoculum (*G. mosseae*)) and biochar application (0 and 1%), and three irrigation levels (50%, 75%, 100% of field capacity) was studied under greenhouse conditions as a pot experiment. For the biochar material, the material that emerged after the maize residues were exposed to the pyrolysis process at 500 degrees was used. The experiment was designed according to a 3-factor randomized plot design.

In order to prepare the soils for analysis after harvest, the soil samples were dried at room temperature (~25 0C) for 15 days and passed through a 2 mm sieve. Determined soil analyzes of the sieved soil by Güzel et al. (1990). At the end of the experiment, the shoot and the root were harvested together and dried in an oven at 70 °. Then, the green parts and root dry weights of the plants were taken, and the green parts were ground and made ready for analysis. K, P and Zn contents of homogenized samples were determined by using an inductively coupled plasma optical emission spectrometry (ICP-OES) device in the extracts obtained by dry burning method. (Kacar and İnal, 2008) Carbon and nitrogen analyzes of soil and plant samples were made with the help of the Fisher-2000 CN analyzer. In order to determine the organic carbon content of the soil samples, the process of subtracting the amount of inorganic carbon in the lime from the total carbon was used. (OC = TC–IC.) Lime analysis was performed with the aid of Scheibler calcimeter (Ülgen and Yurtsever, 1995).

Different package programs were used for the statistical processing of the data of the study. All data were analyzed by a three-way analysis of variance (ANOVA). The smallest differences were made with the Tukey test. The Principal Component Analysis (PCA) of the data was performed with the help of the Excel Stat-14 package program. The Origin pro 20-package program was used for the correlation analysis of the study. Applying biochar to the soil, determining the field capacity, and measuring and supplementing the missing water are given in Figure 1. An image of the trial plant is given in Figure 2.

Figure 1. Applying biochar to the soil, determining the field capacity, measuring, and supplementing the missing water.

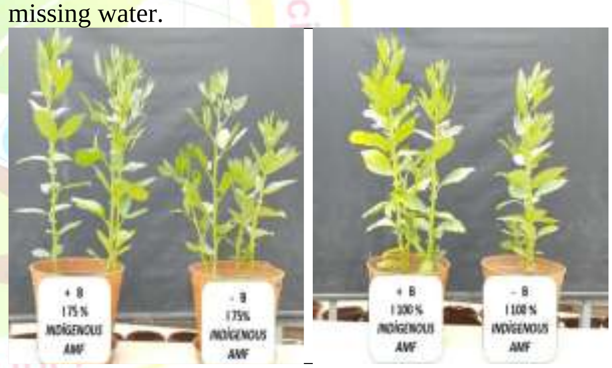

Figure 2. An image of the experiment

RESULTS AND DISCUSSION

Tendency of Carbon and Nitrogen in Soil under Restricted İrrigation Conditions

The differences in the percentages of organic carbon (OC) and nitrogen (N) formed in the soil as a result of biochar and mycorrhiza added to the soil under limited irrigation conditions applied at different levels are given in Figure 3.

When the data obtained were examined, it was concluded that the triple of restricted irrigation (I), Biochar (B) and Mycorrhiza did not form a statistical interaction in the OC % and N% values of the soil.

When the OC values of the soil were analyzed, according to the results obtained, the highest OC% value was obtained as 0.54 % in +B*I75* *G. mosseae* applications, while the lowest OC% value was obtained in -B*I50*Control applications as 0.22 %.

When the N values of the soil were examined, the highest N% value was obtained as 0.092% in +B*I50*Control applications, while the lowest N% value was obtained as 0.044% in -B*I75*Control applications.

C/N values calculated according to the results obtained in the study are given in Figure 4. The effect of the triple interaction on C/N values was not statistically significant. When the results were examined, the highest C/N value was 7.22 in the +B*I100*Control application, while the lowest C/N value was 4.28 in the -B*I50*Control application. According to the results obtained, it is seen that the biochar applied to the soil increases the C/N value of the soil.

Ortas et al. (2013) reported that Organic matter applications applied to the soil increased the OC, N % and C:N parameters compared to the control. The literature information given supports the data obtained as a result of the application of biochar in the study. In general, the average C:N ratios of soils range from 9.9 for arid soils to 25.8 for Histosol soils. (Batjes, 1996). Because the soil employed in our study was poor soil and located in a dry environment, the value of C/N fell between 4.28 and 7.22. According to Jabborova et al. (2022) investigated the effects of biochar and mycorrhiza on the growth of soybean plants and against drought in their study under limited irrigation conditions. As a result of the examination, it was reported that the dual applications of AMF and biochar had a positive effect on 28.3% of microbial biomass compared to the control, the number of AMF spores, and several other parameters in drought conditions.

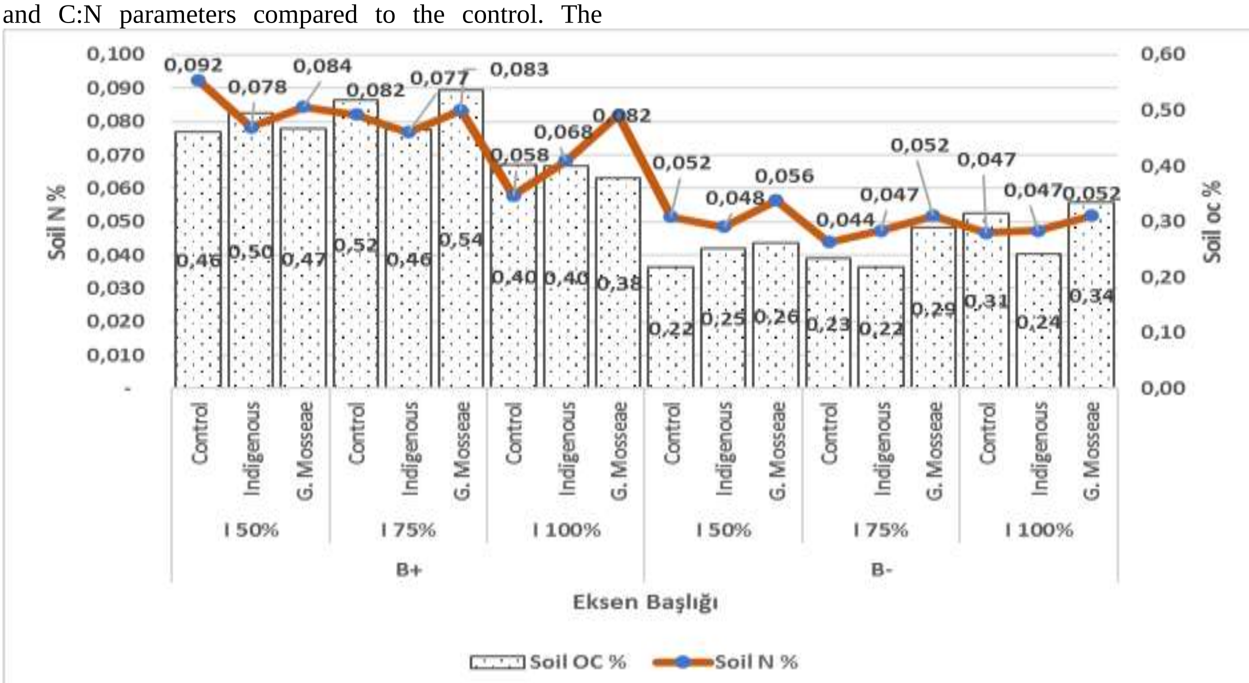

Figure 3. Effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on soil OC and N

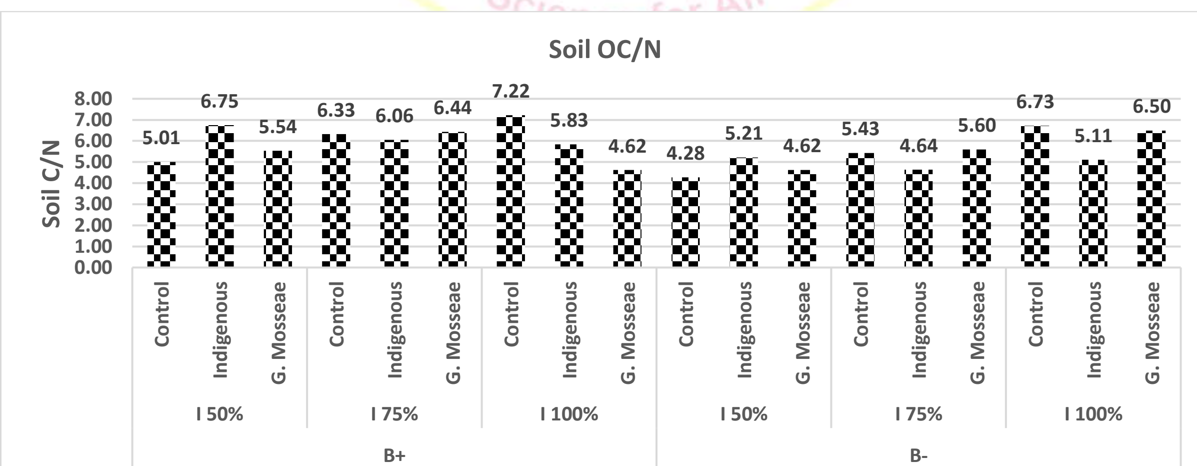

Figure 4. The effect of biochar and mycorrhiza applied to the soil under restricted irrigation conditions on the C/N of the soil.

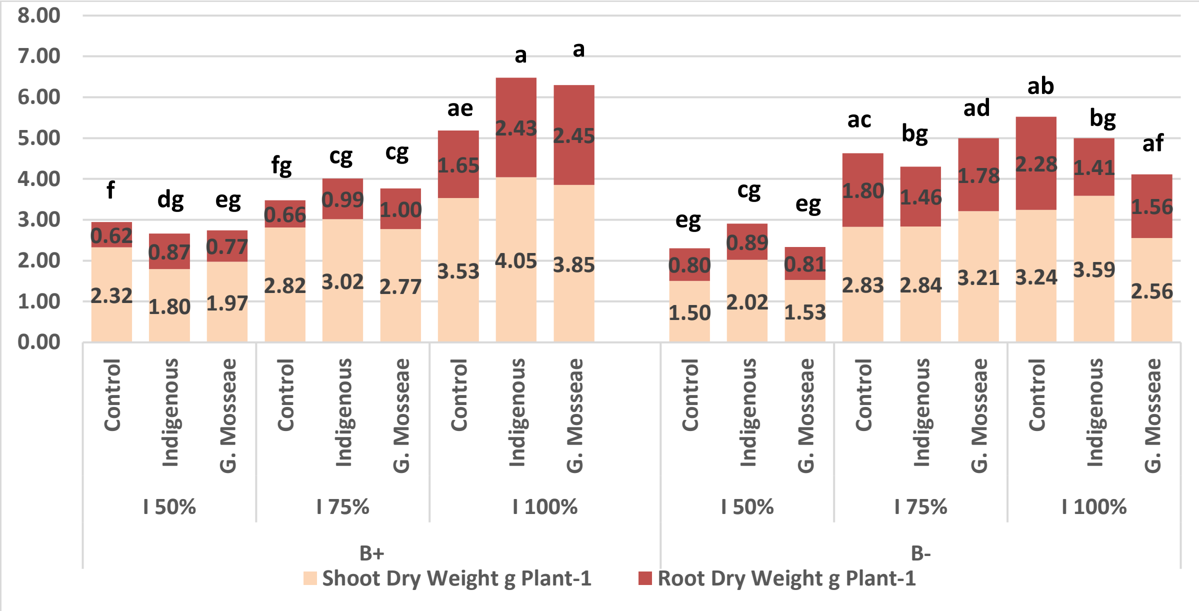

Figure 5. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot dry weight of the plant. *(The letterings are given for the dry weight values of the plant root and the differences are revealed by the tukey test.).*

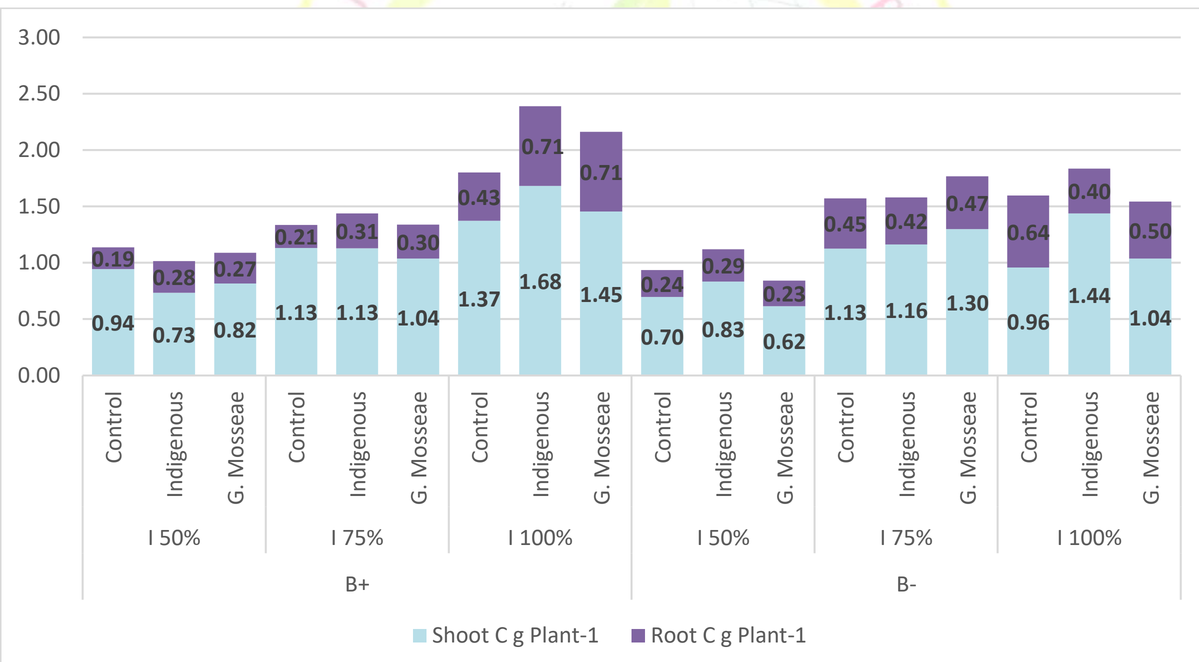

Figure 6. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot C content of the plant.

The Effect of Biochar and Mycorrhiza Applied Under Limited İrrigation Conditions on The Dry Weight of The Plant.

The root and shoot dry weight values of the broad bean plant grown in the area where biochar and mycorrhiza inoculation were added to the soil under limited irrigation conditions applied at different levels are given in the Figure 5.

According to the results obtained, it is seen that there is a triple B*I*M interaction on root dry weight values of the broad bean plants and this interaction is seen to be statistically significant, while its effect on shoot values is not statistically significant.

When the root values of the broad bean plant are examined, the highest root dry weight value was obtained as 2.45 g plant^{-1} in the +B*I100*G.Mosseae application, while the lowest root dry weight value was obtained as 0.62 g plant^{-1} in the +B*I50*Control application.

When the shoot values of the broad bean plant were examined, the highest shoot dry weight value was obtained as 4.05 g plant^{-1} in the +B*I100* *G. mosseae* application, while the lowest shoot value was obtained as 1.50 g plant^{-1} in the -B*I50*Control application.

According to Sobhani et al. (2022) studied biochar, mycorrhiza, and different nitrogen dollars in their study and reported that 4 tons/ha biochar, 100 kg N/ha application, and AMF inoculation had a beneficial and effective role in increasing the growth and yield of wheat.

The Effect of Biochar and Mycorrhiza Applied Under Restricted Irrigation Conditions on Carbon and Nitrogen Content of The Plant.

Root and shoot carbon values of the broad bean plant grown in the area where biochar and mycorrhiza inoculation were added to the soil under limited irrigation conditions applied at different levels are given in Figure 6, and nitrogen values are given in Figure 7. When the carbon and nitrogen contents of the broad bean plant are examined, it is seen that the triple interaction does not have a statistically significant effect on the root and shoot values.

When root and shoot carbon contents are examined, it is seen that the highest root and shoot carbon content values are 0.71 C g plant^{-1} and 1.68 C g plant^{-1}, respectively, in +B*I100*Indigenous pots, while the lowest root and shoot carbon values are 0.19 C g. plant^{-1} and 0.62 C g plant^{-1} were obtained in +B*I50*Control and -B*I50* *G. mosseae* applications, respectively. When root and shoot nitrogen contents are examined, it is seen that the highest root and shoot nitrogen content values are 0.05 N g plant^{-1} and 0.1 N g plant^{-1}, respectively, in +B*I100*Indigenous pots, while the lowest root and shoot nitrogen content values are respectively. It is seen that it is in the pot of -B*I150*G.Mosseae as 0.02 N g plant^{-1} and 0.05 N g plant^{-1}.

In +B*I100*Indigenous pots, where root and shoot nitrogen contents were tested, the maximum root and shoot nitrogen content values were 0.05 N g plant^{-1} and 0.1 N g plant^{-1}, respectively, while the lowest root and shoot nitrogen content values were. It can be seen that there are two plants in the pot of -B*I150**G. mosseae*, each weighing 0.02 and 0.05 g.

According to Wen et al. (2022) , mycorrhizal colonization rate exhibited a significant positive correlation with soil nutrient availability, including phosphorus, potassium, microbial carbon, and nitrogen. As a result, the growth in plant nutrient accumulation was brought on by the interaction of biochar and AMF with mycorrhizal colonization. Zhao et al. (2022) investigated how nitrogen, mycorrhiza, and biochar affected the growth of crowgrass and found that biochar greatly boosted the mycorrhizal colonization rate.

The Effect of Biochar and Mycorrhiza Applied Under Restricted Irrigation Conditions on P, K and Zn Content of the Plant.

Figure 8 shows the wide bean plant's root and shoot phosphorus (P) levels. Figures 9 and 10 show the plant's potassium (K) and zinc (Zn) contents. Using the collected data, it was determined that the root P content of the broad bean plant ranged from 1.52 mg plant^{-1} in the +B*I75**G. mosseae* pot to 2.88 mg plant^{-1} in the +B*I100**G. mosseae* inoculated pots. The maximum shoot P value was found to be 4.71 mg plant^{-1} in the +B*I100*Control pot, and the lowest shoot p content was found to be 3.12 mg plant^{-1} in the -B*I50*Control pot when the p contents of the broad bean plant's shoot values were analyzed.

According to the data obtained, the differences resulting from the effect of triple interaction on the root K contents of the broad bean plant were found to be statistically

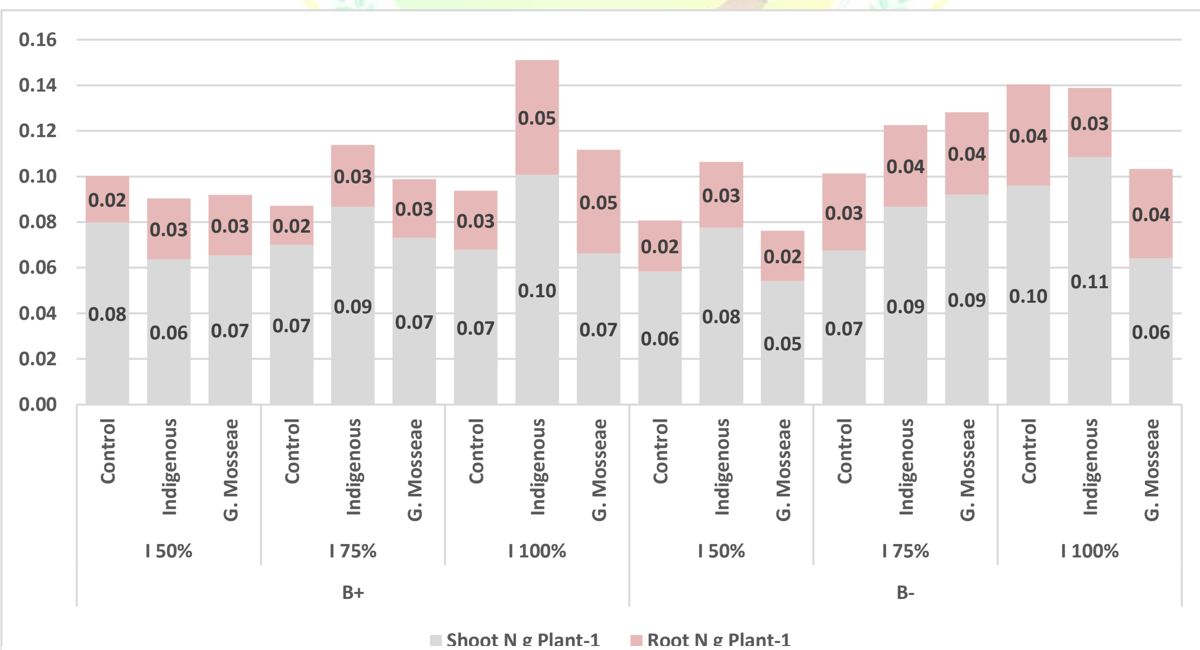

Figure 7. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot N content of the plant.

significant. The highest root K content was obtained as 47.3 mg plant-1 in a +B*I100*Indigenous pot, while the lowest root K content was obtained as 6.5 mg plant-1 in -B*I50*Control pot. When the k contents of the shoot values of the broad bean plant were examined, the highest shoot k value was 105.4 mg plant^{-1} +B*I100*G. While it was obtained in Mosseae pot, the lowest shoot k content was obtained as 35.9 mg plant-1 in -B*I50*Control pot.

According to the data obtained, the highest Zn content for the root and shoot contents of the broad bean plant was 39.6 and 121 µg plant-1 in +B*I100*G.Mosseae pot, while the lowest root and shoot Zn content was 11.1 µg plant-1 and 44.8 µg. plant-1 was also obtained in a-B*I50*Control and -B*I50**G. mosseae* pots, respectively.

Sun et al. (2022) discovered that maize plants were grown in pots treated with biochar and AMFs, either separately or together, and that individual applications of either biochar or AMFs determined maize growth and mineral contents (P, K, Ca, Na, Mg, Fe, Mn, and Zn). They came to the conclusion that the application of biochar and AMFs can affect maize growth, nutrient uptake, and physiological properties.

particularly in the roots and shoots, are positively correlated. Additionally, there is a favorable correlation between the shot carbon content and the P, K, and Zn contents of the plant.

The Principal Component Analysis (PCA) prgram produced values are given in Figure 12, and the eigenvalue values and KMO analysis are given in Table 1. Field (2000) stated that the lower limit for the KMO test is 0.50 and that the KMO test results above this limit value are suitable for principal component analysis of the data considered to be evaluated. Since our obtained KMO value is 0.6245, it is seen that the data are suitable for PCA.

In order to ascertain the correlations between applications and parameters, the data collected as a consequence of mycorrhiza and biochar applications inoculated into pots with varying irrigation levels underwent Principal Component Analysis (PCA). Figure 12 displays the PCA analysis's outcome. The F1 value changed by 51.95 percent and the F2 value by 18.78 percent when the effects of mycorrhiza and biochar treatments inoculated into the pots with various watering levels are evaluated. Since the resultant F1+F2 value is greater than 60% (70.76%), it can be shown that the PCA

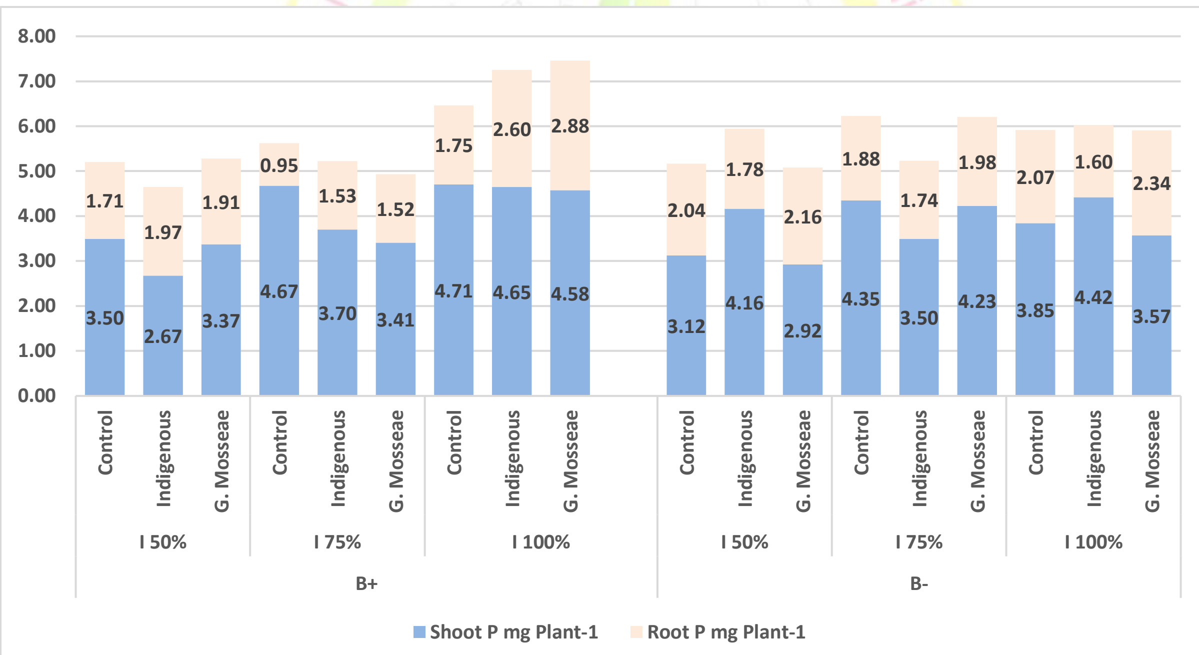

Figure 8. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot P content of the plant.

Correlation And PCA of Data Obtained As A Result Of Different Irrigation Levels, Biochar And Mycorrhiza Applications

Figure 11 displays the findings of the correlation analysis conducted using the obtained parameters. The dry weight of the bikini is positively correlated with several parameters, and these connections are strong, when the data acquired as a result of varying irrigation levels, charcoal applications, and mycorrhiza applications are evaluated. The plant's dry weight and its carbon content,

analysis produced a good explanation for the data. When the eigenvalue values are examined, it is seen that they are above 1 for all F values.

When the results obtained are examined, it is seen that more data are clustered in areas where irrigation is 100% and 75% and there is a positive relationship. It is seen that biochar gives better results in pots with full irrigation than with limited irrigation, and the data are clustered in this area.

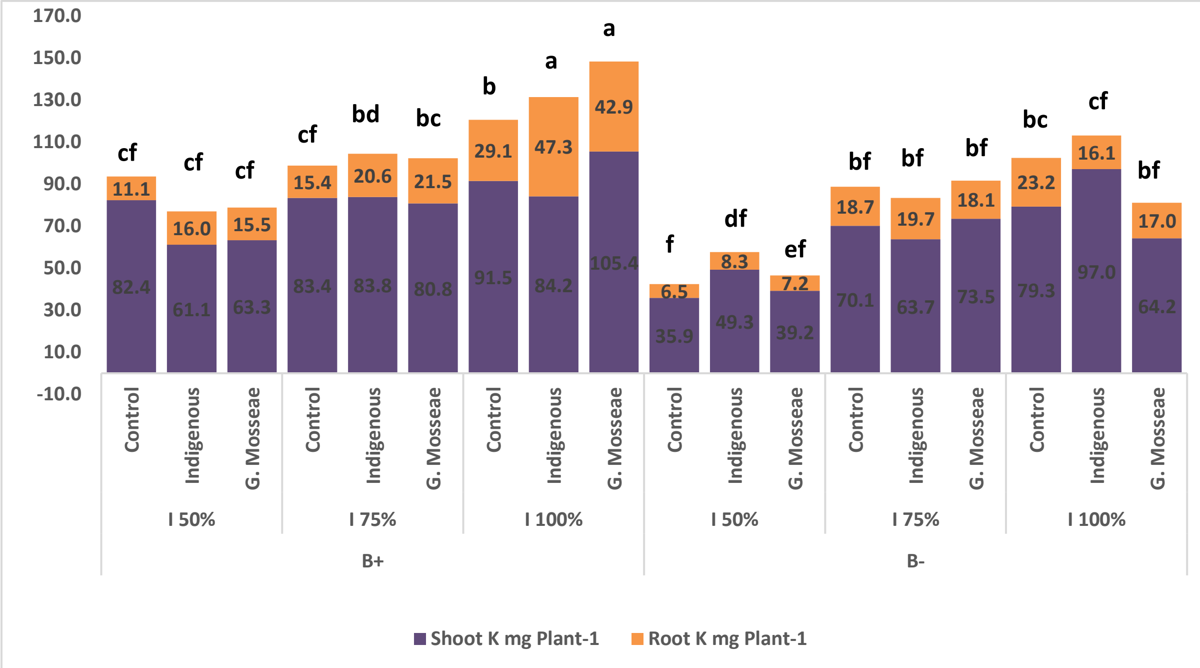

Figure 9. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot K content of the plant. (Letterings are given for Root K values and differences between letters are obtained by Tukey test.)

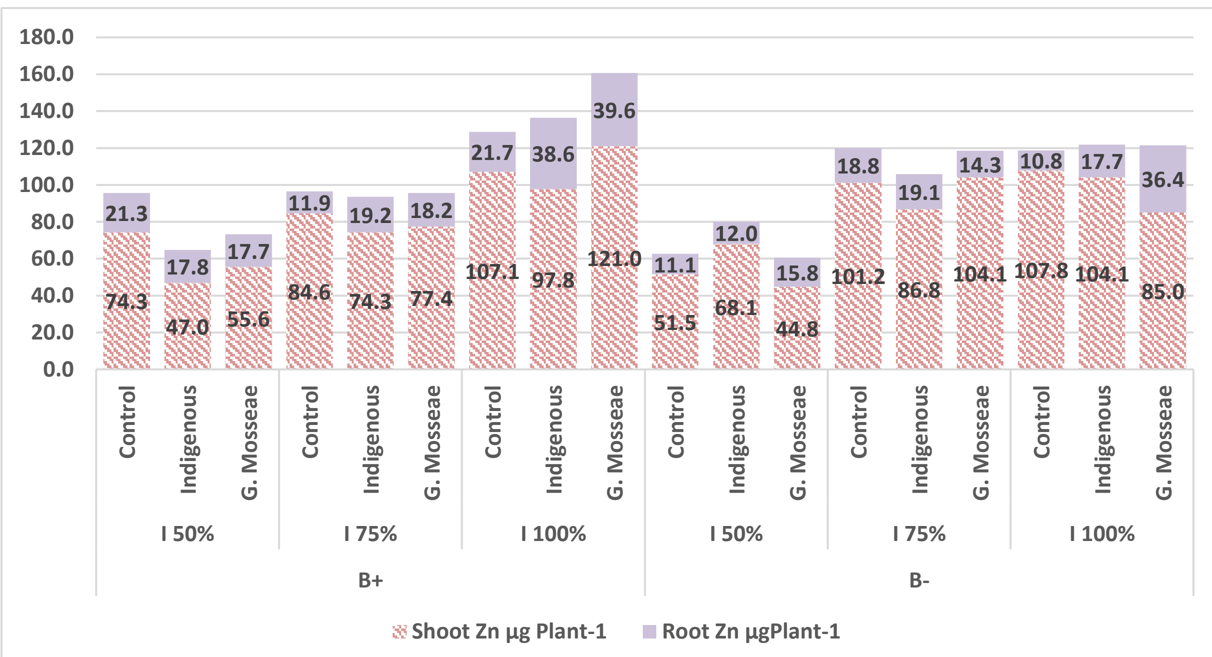

Figure 10. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot Zn content of the plant.

Table 1. Eigenvalue values and the value obtained as a result of KMO analysis

	F1	F2
Eigenvalue	7,7969	2,8170
Variability (%)	51,9791	18,7797
Cumulative %	51,9791	70,7588
Kaiser-Meyer-Olkin measure of sampling adequacy (KMO)	0,6245	

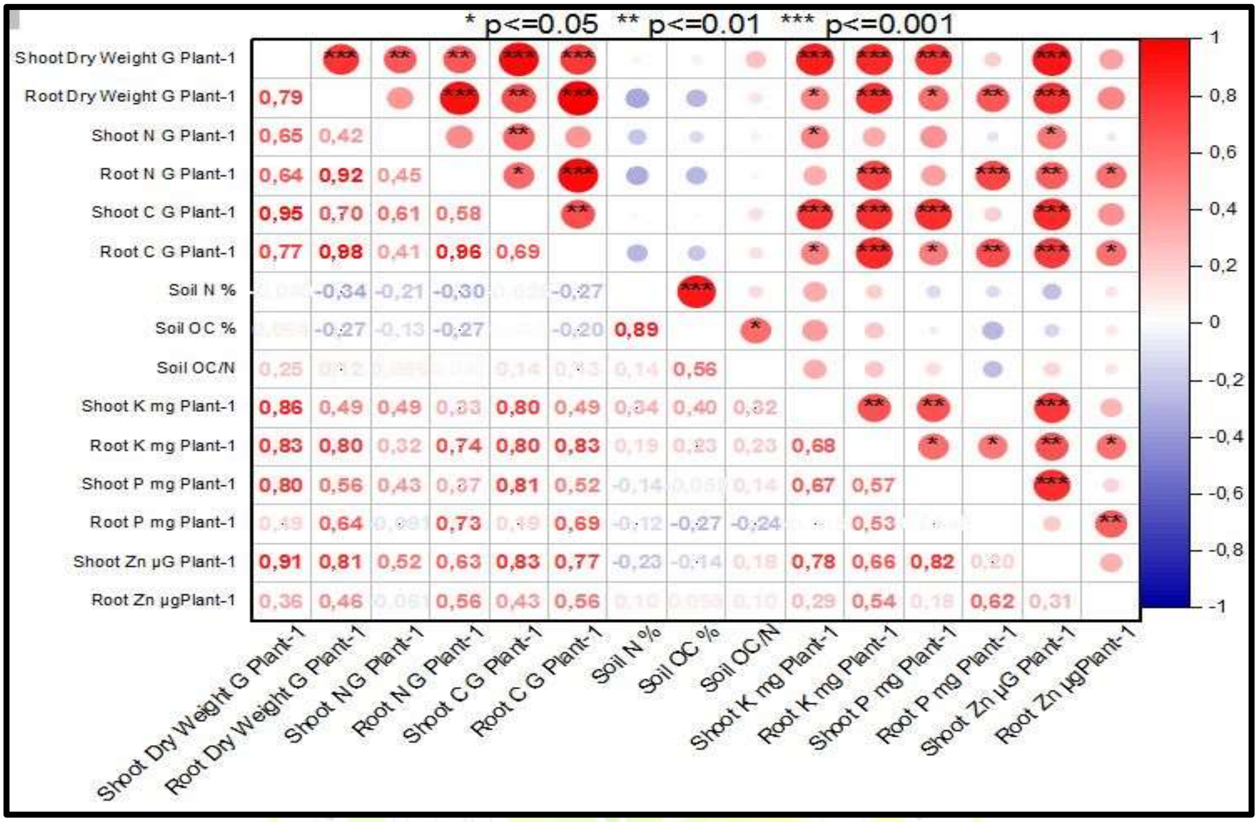

Figure 11. Correlation of The Parameters Obtained As A Result of Biochar and Mycorrhiza Applied To The Soil Under Limited Irrigation Conditions

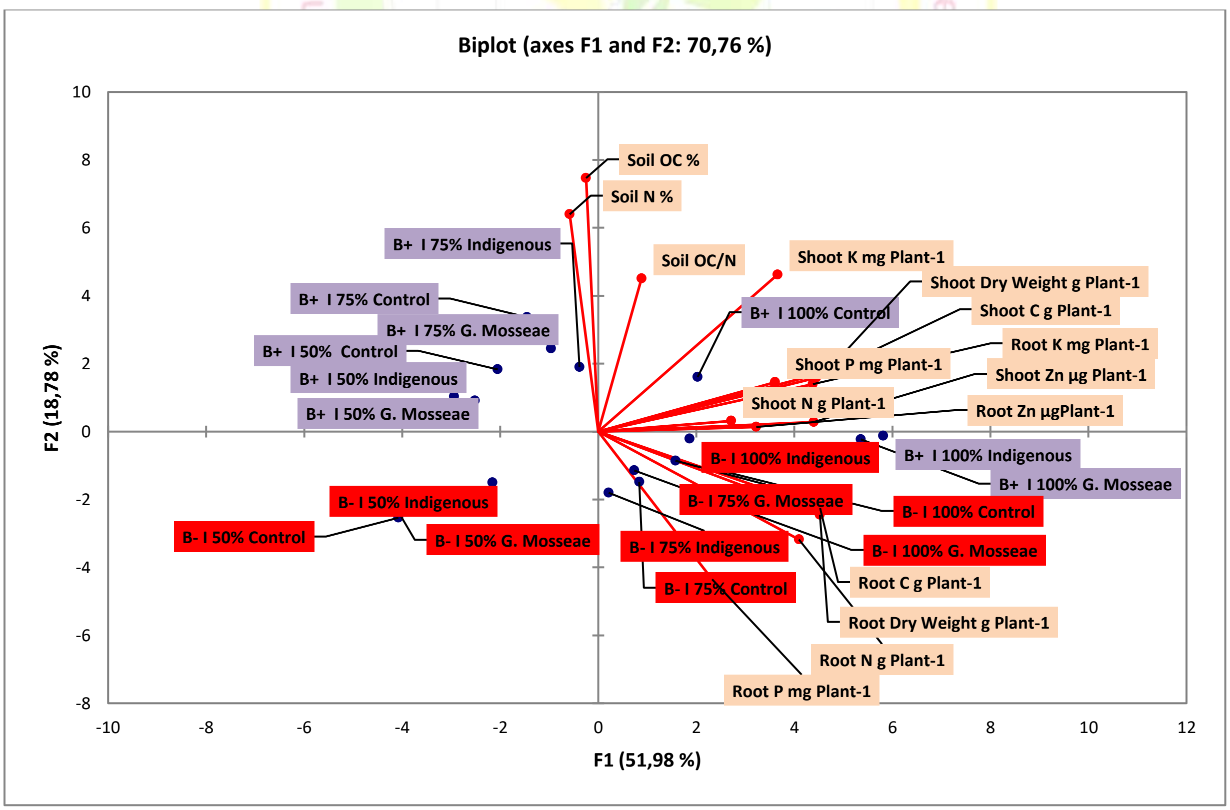

Figure 12. Principal Component Analysis (PCA) analysis of the obtained values.

CONCLUSIONS

The study concluded that the greatest results in terms of soil and plant characteristics were obtained when biochar was applied along with irrigation at a level of I100. The greatest soil organic carbon (OC%) values were obtanied with those treated with both biochar and mycorrhiza (*G. mosseae*). The soil organic carbon to nitrogen (OC/N) ratio was highest in the biochar-equipped pot with full irrigation (I100). The best results were obtained in pots where biochar was applied together with full irrigation, despite the fact that mycorrhizae showed variances in all parameters when taking into account plant parameters (I100). Based on the study's findings, it is evident that the biochar application and I100 level produce the best outcomes.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

REFERENCES

Abdullah, M. M., Assi, A., Zubari, W. K., Mohtar, R., Eidan, H., Al Ali, Z., Al Anzi, B., Sharma, V. K., and Ma, X. M., 2022. Revegetation of native desert plants enhances food security and water sustainability in arid regions: Integrated modeling assessment. *Science of the Total Environment* **806** 10.

Akşahin, V., Işik, M., Öztürk, F., Jan, S. U., and Ortaş, İ.2019 . Effect of Phosphorus (P) Level Application on Soil Structure Development. In "International Soil Congress 2019", pp. 375-379, Ankara Turkey.

Batjes, N. H., 1996. Total carbon and nitrogen in the soils of the world. **47** (2): 151-163.

Çakmak, B., and Gökalp, Z. 2013. Kuraklık ve tarımsal su yönetimi. *Gaziosmanpaşa Bilimsel Araştırma Dergisi* (**4**): 1-11.

Field, A. 2000. Discovering statistics using SPSS for windows sage publications. London 2 44-322.

Güzel, N., Gülüt, K. Y., Ortaş, İ., and İbrikçi, H. 1990. "Toprak Verimlilik Analiz Yöntemleri Laboratuar El Kitabı."

Jabborova, D., Annapurna, K., Azimov, A., Tyagi, S., Pengani, K. R., Sharma, P., Vikram, K. V., Poczai, P., Nasif, O., Ansari, M. J., and Sayyed, R. Z. 2022. Co-inoculation of biochar and arbuscular mycorrhizae for growth promotion and nutrient fortification in soybean under drought conditions. *Frontiers in Plant Science* 13 9.

Kacar, B., and İnal, A. 2008. Bitki Analizleri. Nobel Yayın No: 1241. *Fen Bilimleri* 63 (1).

Kopittke, P. M., Menzies, N. W., Wang, P., McKenna, B. A., and Lombi, E. 2019. Soil and the intensification of agriculture for global food security. *Environment International* 132.

Lehmann, J. 2009. Biological carbon sequestration must and can be a win-win approach. *Climatic Change* **97** (3-4): 459-463.

Ortas, I., Akpinar, C., and Lal, R. 2013. Long-term impacts of organic and inorganic fertilizers on carbon sequestration in aggregates of an Entisol in Mediterranean Turkey. *Soil Science* **178** (1): 12-23.

Sobhani, S. M. A., Alavifazel, M., Ardakani, M. R., Modhej, A., and Lak, S. 2022. Influence of mycorrhizal fungi and biochar on nitrogen use efficiency correlated with yield and yield components of wheat. *Plant Science* Today **9** (3): 509-517.

Sun, J. H., Jia, Q., Li, Y., Zhang, T., Chen, J. Y., Ren, Y. A., Dong, K. L., Xu, S., Shi, N. N., and Fu, S. L. 2022. Effects of Arbuscular Mycorrhizal Fungi and Biochar on Growth, Nutrient Absorption, and Physiological Properties of Maize (Zea mays L.). *Journal of Fungi* **8** (12): 15.

Ülgen, N., and Yurtsever, N. 1995. "Türkiye Gübre ve Gübreleme Rehberi," Baskı, Ankara, Köy Hizmetleri Genel Müdürlüğü, Toprak ve Gübre Araştırma Enstitüsü Müdürlüğü Yayınları, Genel Yayın No: 209, Teknik Yayınlar No: 66, 4.

Wen, Z. H., Chen, Y. X., Liu, Z. Q., and Meng, J. 2022. Biochar and arbuscular mycorrhizal fungi stimulate rice root growth strategy and soil nutrient availability. *European Journal of Soil Biology* **113** 10.

Zhao, Z. J., Chen, L., and Xiao, Y. 2022. Biochar Shifts the Negative Effect of N Addition on Lotus corniculatus L. Growth in TEs Contaminated Soil, Regardless of Exogenous Arbuscular Mycorrhizal Fungi Inoculation. *Journal of Soil Science and Plant Nutrition* **22** (4): 4883-4896.

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