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Research Article

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The Effect of Mycorrhiza Inoculation on Pepper Plant Growth and Mycorrhizal Dependency

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ABSTRACT
Pepper cultivation is one of the vegetables that are widely produced in the world. The use of mycorrhiza in sustainable agriculture can be an environmentally friendly and economical agriculture strategy. The purpose of the study; is to investigate the effect of mycorrhiza inoculation on plant growth development, yield and mycorrhizal dependency. The hypothesis to be tested is; inoculation of mycorrhiza increases pepper plant growth parameters. The experiment was established as a pot experiment under greenhouse conditions in February 2018 and harvested in April 2018. BT 16-90 F1 pepper (*Capsicum annuum* L.) species seeds were used with mycorrhiza *Claroideoglomus Etunicatum* and without mycorrhiza inoculation with three replications. Before harvesting, plant height and leaf diameter were measured. At harvest, the dry and fresh weights of the root and shoot were measured. In addition, some of the root morphological properties (like root diameter, root length, root surface area and root volume) were determined by using WinRhizo program. In addition, mycorrhizal root infections were determined. Mycorrhizal dependency was calculated by using dry matter data. Research findings showed that mycorrhizal inoculation increased pepper plant root, shoot fresh and dry weight, plant height, and leaf diameter. In addition, the root length of the plants with mycorrhiza inoculation (as 3921 cm pot^{-1}) was higher than without mycorrhiza (with 1945 cm pot^{-1}) treatments. The pepper plant has a high mycorrhizal dependency (71.9%) with *Cl. Etunicatum* inoculation. The results shown that *Cl. Etunicatum* inoculation increased pepper plant growth and development. Also, the pepper plant is a highly mycorrhiza-dependent plant.
Keywords: Pepper, Mycorrhizal Dependency, Shoot and Root Growth

INTRODUCTION

Pepper is very important produced vegetables in world. It is a plant with numerous varieties. Initially, it originated from Americas; but recently pepper has cultivated to Asia, Africa and Mediterranean. Pepper was commonly used for medicinal purposes and its usage and cultivation may be around 5000 years ago as historically (Moreb et al., 2020). Pepper is a rich source of carotenoids, phenolic compounds, and antioxidants. Moreover , a medium-sized pepper be able contain up to 200% of a person's daily requirement of vitamin C (Hallmann & Rembiałkowska, 2012). In addition, pepper contains many nutrients for instance; fibers, fats, proteins and carbohydrates and micro elements such as Zn, Cu and Fe (Ananthan et al., 2014, Moreb et al., 2020). Due to the abundance of these, there were so many studies have focused on the health benefits of consuming pepper (Clark & Lee, 2016, Moreb et al., 2020, Wang et al., 2006). Pepper plants are commonly used in food, medicine and paint industries (Aybak, 2002). Previous studies also showed that pepper plants are mycorrhizal dependent (Baum et al., 2015, Ortas et al., 2011, Sensoy et al., 2007).

Mycorrhiza which live mutualism with around 80% of terrestrial plants (Egerton-Warburton et al., 2005), provide plants with water and nutrients (Khan & Rao, 2019), as well as resistance to diseases and pests, resistance to drought stress and increased the plant growth (Smith & Read, 2010). Moreover, there are various studies showing that mycorrhiza inoculation increases pepper growth (Douds Jr & Reider, 2003, Ortas et al., 2011, Sensoy et al., 2007). Plants have a good root and shoot system to get more nutrition and photosynthesis. These days, it has great importance to use natural resources in agriculture in a sustainable way. Therefore, using a sustainable resource such as mycorrhizal fungi in agriculture can prevent excessive fertilizer use and will also be more economical and eco-friendlier.

Although there are studies in the literature about the effect of mycorrhiza inoculation on pepper growth, we still do not have enough information about the effect of mycorrhizae on pepper as compared to other commercially important crops (Al-Karaki, 2017). In this respect, the aim of the study; is to investigate the effect of mycorrhiza inoculation on plant growth development,

yield and mycorrhizal dependency of pepper plants. The hypothesis to be tested is; inoculation of mycorrhiza increases pepper plant growth parameters.

MATERIALS AND METHODS

The experiment was established in February 2018 in Department of Soil Science and Plant Nutrition Research and Application Greenhouses, Cukurova University Faculty of Agriculture. BT 16-90 F1 pepper variety was taken as the host plant and (*Cl. Etunicatum*) was used as the mycorrhiza species. Andesitic tuff (Urgup stone) + soil (Menzilat soil series) was used as 9:1 volume ratio for growing medium in the experiment. The experiment was established in three replications with mycorrhizae (+M) and without mycorrhizae (-M) according to the completely randomized design (CRD) of experiment. In order to eliminate microorganisms that may compete with mycorrhizae in the medium and to better see the effectiveness of mycorrhizae, the growing medium used in the research was autoclaved for sterilization purposes in an autoclave at 120^0C under 2 atm of pressure for 2 hours. 2 L of pots were use in the experiment and harvested in April 2018. Before harvesting, the height of the plants and leaf diameters were measured. Immediately after harvest, wet and dry matter yields of root and shoot of the plants were taken. In addition, plant root morphological characteristics were analyzed using WinRhizo program and root infection was performed according to Koske and Gemma (1989). With the data obtained, Mycorrhizal Dependence (MD) was calculated according to (Ortas, 2012). Formula of MD is shown in equation 1. ANOVA analysis and LSD test were made with JMP 8 package program. Origin 2022 package program was used for correlation matrix of variates in Figure 6.

$$MD = \frac{(+M)\ Dry\ Weight - (-M) DryWeight}{(+M) Dry\ Weight} x100$$

(Equation 1)

RESULTS AND DISCUSSION

Effect of Mycorrhiza Inoculation on Pepper Fresh and Dry Weights

Figure 1 shows how mycorrhizal inoculation affected the fresh weight of the pepper's root and shoot. Both Table 1 and Figure 1 shown that mycorrhizal inoculation significantly improved the fresh weight of pepper root ($P<0.01$) and shoot ($P<0.05$). As presented in Figure 1, the fresh weight of the root and shoot that received +M pots (with 8.9 g pot^{-1} and 3.2 g pot^{-1}) was statistically higher than that of the control group (with 7.7 g pot^{-1} and 3.0 g pot^{-1}) without mycorrhiza. As seen in Figure 6, there was strong positive correlation (r = 0.93) between root infection and root fresh weight, as well as there are also positive correlation (r = 0.91) between root infection and shoot fresh weight. Mycorrhiza inoculation was expected to increase pepper fresh weight. There are many studies in the literature that mycorrhizal fungus enhances pepper growth. For example; Haghighi and Barzegar (2018) reported that mycorrhiza inoculation increased pepper growth in their study. Moreover, Balog et al. (2017) reported that mycorrhizal inoculant improved plant yield in their study.

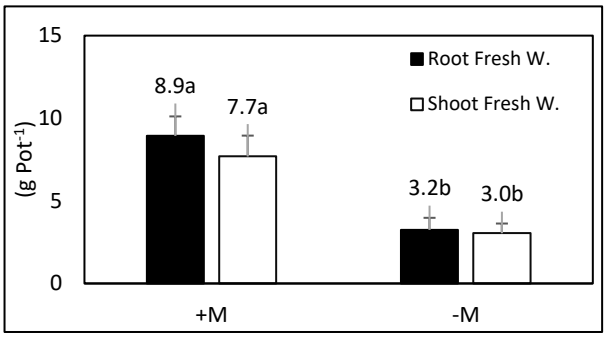

Fig. 1. Impact of mycorrhizal inoculant on fresh weight in different parts of pepper (root and shoot)

Figure 2 shown how mycorrhizal inoculation affected the dry weight of the roots and shoots. In comparison to plants without mycorrhiza inoculation, plants with mycorrhiza inoculation demonstrated a statistically significant difference as pepper dry matter. Moreover, +M plants had greater increases in shoot dry weight than -M plants. Root dry weights for +M and -M had 0.59 g pot^{-1} and 0.17 g pot^{-1}, respectively. Mycorrhizal fungi are known to improve yield by giving the host plant nutrients and water. Our research findings, are supported by Hegazi et al. (2017) study that mycorrhizal inoculation enhanced pepper dry matter. In addition, Ortas et al. (2011) in their study investigated the impact of different mycorrhiza, P and Zn applications on pepper P and Zn uptake under greenhouse conditions. The research findings of the study showed that mycorrhiza inoculation was increase pepper dry matter yield and the study supports our research findings. Furthermore, there was a positive strong correlation (r=0.96-0.99) between dry and fresh weight of pepper in Figure 6. The relation between dry weight (root and shoot) and mycorrhizal infection is also observed to be positive and high (r = 0.94-0.97).

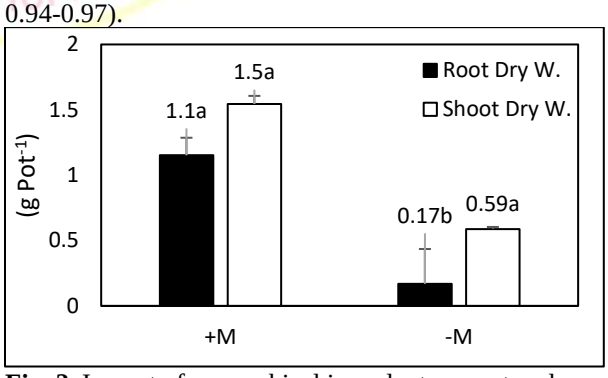

Fig. 2. Impact of mycorrhizal inoculant on root and shoot dry weight

Impact of Mycorrhiza Inoculation on Pepper Plant Height and Leaf Diameter

It is seen the impact of mycorrhizal application on height and leaf diameter of pepper in Figure 3. The height and leaf diameter of plants having mycorrhizal innoculation

were statistically more than non-mycorrhiza inoculated plants (for the height P>0.001 and for the leaf diameter P>0.01) in Table 1. Mycorrhiza inoculation increased pepper plant height by 26.6% and leaf diameter by 16.6% as seen in Figure 3. It is expected that mycorrhizal fungi, which increase plant yield and nutrition, also increased some plant morphological characteristics such as plant height and leaf diameters. Temperini et al. (2008) show that inoculated different pepper varieties with mycorrhizae and measured some plant yield and growth parameters in their work. In this study, mycorrhiza inoculation generally increased pepper height and leaf number and their study supports our research findings. In addition, there are positive correlation between mycorrhzal infection and pepper plant height and leaf diameter (r= 0.98) as seen Figure 6.

Table 1. Level of significance for effects of increasing phosphorus doses application on fresh weight, dry weight, plant height and leaf diameter, root morphological properties (like diameter, length, surface area and volume), root infection and mycorrhizal dependency.

Root Fresh W.	Shoot Fresh W.	Root Dry W.	Shoot Dry W.	Total Dry W.
**	*	**	*	**
Plant Height	Leaf Diameter	Root Infec.	Root Diameter	Root Length
***	**	*	ND	*
Root Surface A.	Root Volume	M. Dependency		
ND	ND	-		

NS, not significant. *, ** and *** show significant level at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$.

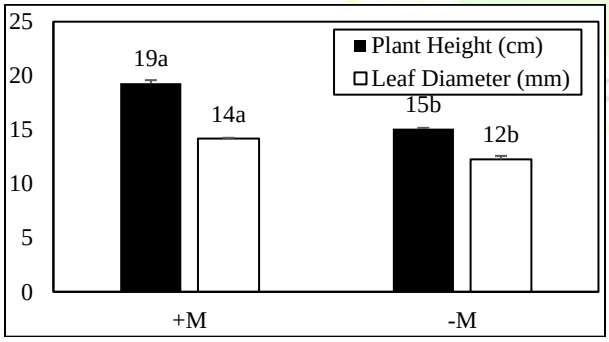

Fig. 3. Impact of mycorrhizal inoculation on height and leaf diameter of pepper

Effect of Mycorrhiza Inoculation on Pepper Root Morphological Properties

It is seen that no statistically difference (P>0.05) as diameter, surface area and volume of root when the effect of mycorrhiza inoculation on some root morphological features of pepper is evaluated (Table 2). However, Tables 1 and 2 show that there was a statistically significant variation in root length. As statistical, +M had a root length of 3921 cm pot^{-1}, which was longer than -M's root length of 1945 cm pot^{-1}, as shown in Table 2. Several studies had shown that the mycorrhizal fungus improved plant root development, particularly root length. Zhang et al. (2017) demonstrated that with mycorrhizal plants have longer roots than without mycorrhiza plants, and their research findings support our study.

Table 2. Effect of mycorrhiza inoculation on pepper root morphological properties

Application	Diameter (mm)	Length (cm pot^{-1})	Surface Area (cm^2 pot^{-1})	Volume (cm^3 pot^{-1})
+M	0.40±0.1	3921±122a	566±23.2	5.11±1.7
-M	0.67±0.1	1945±32b	510±56.1	6.90±1.3

Effect of Mycorrhiza Application on Pepper Root Infection

It is seen effect of mycorrhizal inoculation on root infection in Figure 4. There was no statistically significant difference in mycorhizal infection. However, the average root infection of mycorrhiza-inoculated plants was 40% while the average root infection of non-mycorrhiza inoculated plants was 10%. It's possible that the researchers' sloppy work methods contributed to the 10% infection in plants that weren't treated with mycorrhizae.

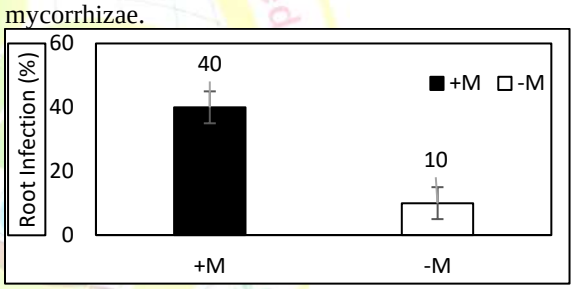

Fig. 4. Impact of mycorrhiza inoculation on pepper root infection (%)

Mycorrhizal Dependency of Pepper

Figure 5 shows that impact of mycorrhiza application on pepper growth. The average mycorrhizal dependence is 71.9 %. There are studies in the literature indicating that pepper is a MD plant (Beltrano et al., 2013, Ikiz et al., 2008). Moreover, according to Ortas et al. (2011) pepper is a MD plant. Moreover, Pınar et al. (2015) described that the pepper is a MD plant.

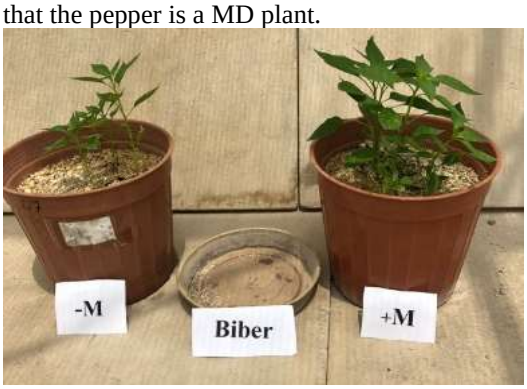

Fig. 5. A picture from effect of mycorrhiza inoculation on plant growth

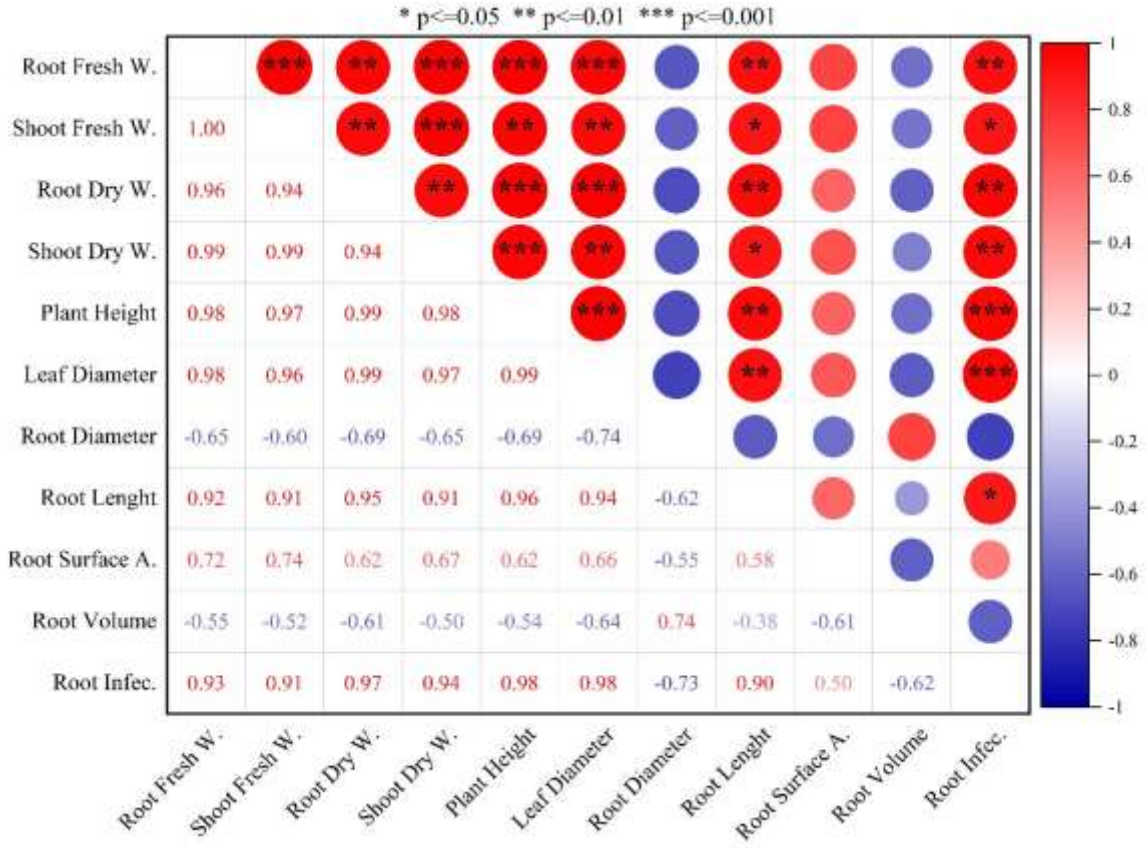

Fig. 6. Correlation matrix of variates

CONCLUSIONS

The research findings of the study proved that mycorrhizal inoculation improved various morphological traits of the portions of pepper's root and shoot, and also its fresh and dry weight yields. Our idea is therefore supported by the research outcomes of our investigation. Additionally, because the pepper plant depends on mycorrhizae for growth, mycorrhiza inoculation can be used in pepper cultivation to rise production in a sustainable and profitable way.

CONFLICT OF INTEREST

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

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