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Improvement of Morpho-Physiological Traits and Antioxidant Capacity of Zinnia (Zinnia Elegance 'Dreamland Red') by Arbuscular Mycorrhizal Fungi (*Glomus mosseae*) Inoculation

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ABSTRACT

Objective: The inoculation of substrates with arbuscular mycorrhizal fungi (AMF) is one of the most important effective strategies applied and one of the aims of sustainable agriculture. **Methods:** This experiment was conducted to evaluate the effects of AMF inoculation (0, 2.5, and 5 W/W) on morpho-physiological traits such as flower and root dry weight, water-use efficiency and antioxidant capacity, based on the completely randomized design with three replications. **Results:** The results showed that AMF has a significant and positive effect on the studied traits compared to the control. Moreover, the highest flower and root dry weight were achieved in 5% AMF. Water use efficiency, antioxidant capacity and total phenol content were 1.5, 1.1 and 1.3 times higher in 5% treatment compared to the control (without AMF), respectively. The results showed the significant and positive symbiosis between *Glomus mosseae* and zinnia bedding plants, which led to improvement of flowers quality.

1.INTRODUCTION

Zinnia (*Zinnia elegans*) as an annual bedding plant with colorful flowers belongs to Asteraceae family (Dole & Wilkins, 2005). Arbuscular mycorrhizal fungi (AMF) are one of the most important microorganisms in the undamaged soils. According to the present estimates about 70% of the soil microbial biomass is formed by the mycelium of these fungi (Mukerji & Chamola, 2003). More than 95 percent of the plants form a mycorrhizal symbiosis, which is usually a bilateral relationship between the fungi and the root of the plant. In this relationship the fungus takes the carbon it needs from the host plant, and in turn subsequently increases the absorption of nutrients, particularly phosphorus by the host plant (Smith et al., 2009). Increased supplying of plant nutrients through the increase in root volume (Smith & Read, 2008), increased yield and productivity (Bolandnazar et al., 2007; Abdel Latef & Chaoxing, 2011), boost in the production of cytokinin and gibberellin plant hormones (Helena Cruz, 2008) and enhancing water, soil and plant relations in a way that results in better adaptation of the plant to unfavorable environmental conditions is amongst the most important advantages of mycorrhizal fungi and plant symbiosis (Robert et al., 2008). Moreover, the symbiosis increases the salt tolerance (Abdel Latef & Chaoxing, 2011) and increases plant resistance to pathogens (Thangaswamy & Padmanbhan, 2006).

The extensive cultivation of zinnia as a bedding plants and the low number of studies regarding the reaction of this flower to symbiosis with mycorrhizal fungi, particularly assessment the effect of the fungi on water-

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use efficiency and physiological traits of zinnia, were the main goals of the present experiment.

2. MATERIALS AND METHODS

This study was carried out on pot over the spring and summer in 2012 based on the completely randomized design with three replications. The experimental treatment included different levels of substrate inoculation with *Glomus mosseae* (0, 2.5 and 5 percent of soil weight). The substrate (soil) was initially autoclaved at 121 ℃ for 20 minutes and then was inoculated with *Glomus mosseae*. Finally, flower and root dry weight, water-use efficiency (Karkaniset al., 2011), antioxidant capacity and total phenol content (Koleva et al., 2002) were measured. Data analysis was conducted using SAS software (9.1 version) and means comparison through Duncan's multiple range test at the 0.05 and 0.01 levels of probability.

3. RESULTS AND DISCUSSION

3.1. Flower dry weight

Results showed the significant effects of AMF on flower dry weight (P<0.05) (Figure 1). Mean comparisons indicate that there is significant difference between different levels of fungi. By increasing the inoculation level, flower dry weight increased 1.9 times compared to the control. The highest (0.95 g) and the lowest (0.48 g) flower dry weights were observed in 5% and control treatments, respectively. One of the reasons for the higher flower dry weight might be the better absorption of nutrients. The nutrients, especially phosphorus are effective in plants' blooming. It seems that it is the increasing absorption of nutrients like phosphorus that by disseminating through mycorrhizal mycelium connected to root's internal tissues and forming an additional absorption system complementing the root system of the plant enables it to exploit higher volumes of soil which roots do not have access to by themselves. With increasing levels of mycorrhizal fungi in petunia flowers, the dry weight of flower increased compared to the control treatment (Shamshiri et al., 2011) which is consistent with the findings of this study on Zinnia.

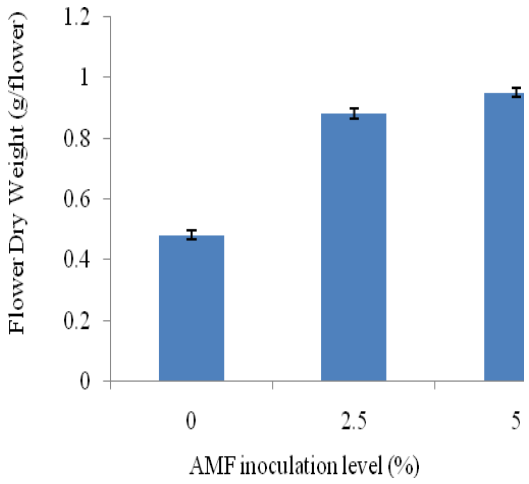

Fig. 1: Effect of *Glomus mosseae* on flower dry weight of zinnia 'Dreamland Red'.

3.2. Dry weight of roots

According to the results of the analysis of variance and comparisons of means, the role of fungus on increasing the weight of dry roots was significant at 5% level of significance. According to the comparison of means there is a significant difference among different levels of fungus. The maximum dry weight of the root was obtained from 5% fungus with .59 mean and the least from the control treatment with 0.29 gram. With increasing levels of fungal root dry weight increased nearly twofold compared to the control (Fig. 2). By their influence on plant's hormones such as decrease in the concentration of auxin and cytokine, the mycorrhizal fungi cause plants' root system development. The increased concentration of auxin in symbiotic plants with mycorrhizal fungus has been reported in a number of studies (Fitze et al., 2005). There are also other studies that indicate the increase in the efficiency of the roots in a mycorrhizal symbiotic condition, including the study of Bolandnazar (2007) on edible onion, which is in line with the findings of this study.

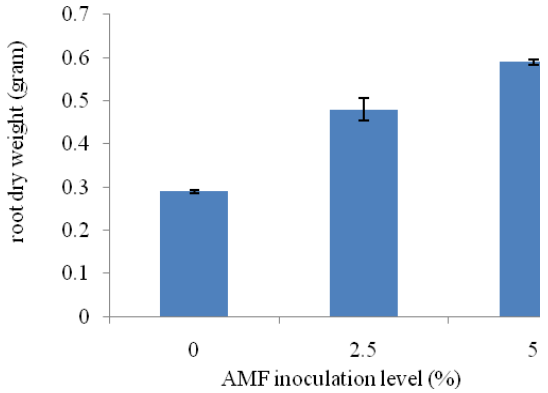

Fig.2: Effect of *Glomus mosseae* on root dry weight of zinnia 'Dreamland Red'

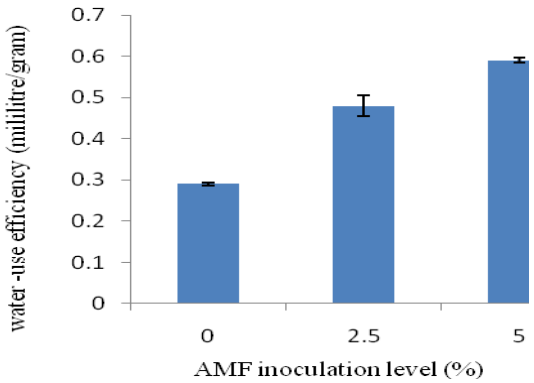

Fig. 3: Effect of *Glomus mosseae* on water-use efficiency of zinnia 'Dreamland Red'.

3.3. Water-use efficiency

Analysis of variance revealed the significant effect of mycorrhizal fungi on the level of this variable ($p < .05$). According to mean comparisons, examining the effect of mycorrhizal fungus on water-use efficiency variable revealed that the 5% fungus treatment resulted in 1.5 time higher efficiency compared to the control treatment (Fig. 3). The results of studies on mycorrhizal and non-mycorrhizal plants have revealed that the hydraulic conductivity of the root system of mycorrhizal plants is more than non-mycorrhizal plants which is due to the increase in root volume or length. Also, the hydraulic conductivity along the root increased 2 to 3 times (Robert et al., 2008; Troehza et al., 2003). Anything that increases the efficiency or reduces the evaporation or sweating would increase water-use efficiency (Sohani, 2000). By controlling stomatal closure and opening of leaves and by increasing the water uptake due to their widespread hyphal network, the mycorrhizal fungi decreases plants' water-related problems such as water uptake and sweating (Roldan, 1982). Similar results of increased water-use efficiency by mycorrhizal colonization were reported by Bolandnazar (2007) which was observed in both sterile and non-sterile soil. Higher water-use efficiency in mycorrhizal plants may indicate that arbuscular fungi can absorb water through the root by developing fungal hyphae and increasing contact surface with soil.

3.4. The antioxidant capacity

According to the analysis of variance, the effect of mycorrhizal fungi on antiradical properties was significant in 5% level of significance. The treatment led to the increase in antiradical properties. According to the results of mean comparisons, no significant difference was observed at 2.5 and 5 percent levels of mycorrhizal fungi. The maximum and minimum levels of antiradical properties in the 5% mycorrhizal fungi and the control treatment were 87 and 80 percent respectively (Fig. 4). According to the results of Ardoghani and Zare (2011), the application of mycorrhizal fungi on tomato led to an increase in the amount of antioxidant capacity of the plant compared to the control conditions (without symbiosis), which is consistent with the findings of the present study on Zinnia.

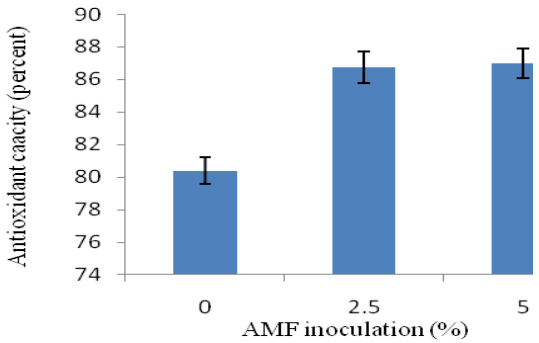

Fig. 4: Effect of *Glomus mosseae* on antioxidant capacity of zinnia 'Dreamland Red'.

3.5. Total phenol of the leaves

Analysis of variance indicates significant effects of the use of mycorrhizal fungi on total phenol of the leaves of Zinnia ($p < .05$). Mean comparison of mycorrhizal fungi treatment showed that 2.5 and 5 percent increased phenol of the plant 1.22 and 1.37 percent respectively (Fig. 5). Mycorrhizal symbiosis in substrate, depending on the concentration, leads to increase in total phenol of the leaves, the reason of which could be provision of more nutrients, especially phosphorus and calcium. A study by Sharifi et al. (2011) on basil revealed that the average amount of total phenol in plants' aerial organs significantly increased in mycorrhizal plants compared to the control treatment which is consistent with the results of the present study.

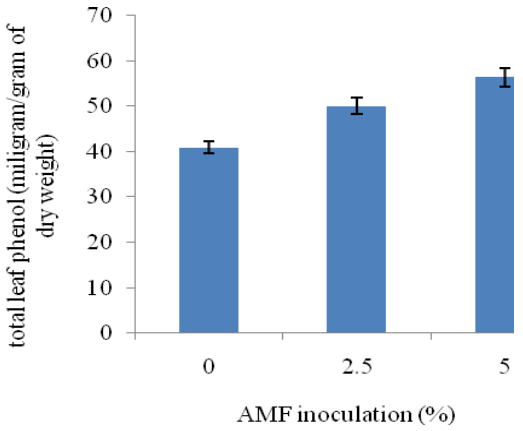

Fig. 5: Effect of *Glomus mosseae* on total phenol weight of zinnia 'Dreamland Red

CONCLUSION

As a result of impregnating the substrate or soaking Zinnia transplant with mycorrhizal fungi, the growth and the quality of flower production, antioxidant capacity and total phenol of the leaves of Zinnia were enhanced compared to the control treatment.

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