Agricultural Marketing and Commercialization Journal
4(2), 1-7, 2020, ISSN Print: 2676640X, ISSN online: 2676-7570

The Effect of Arbuscular Mycorrhizal Fungi on Nutrient Concentrations in Ohadi (Fandoghi) and Kalleghouchi Pistachio Seedlings in Kerman Region

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Abstract

In order to investigate the effect of arbuscular mycorrhizal fungi (AMF) on the concentrations of nutrients in pistachios, a pot experiment was carried out in the greenhouse based on a factorial design in a completely randomized design with three replications and two factors. There were four factors, namely pistachio species at two levels of Ohadi (Fandoghi) and Kalleghouchi cultivars and culture medium factor at three levels (fungi-free non-sterile soil, fungi-free sterile soil, and fungi-containing sterile soil). Plants with AMF and Ohadi and Kalleghouchi pistachio seeds were planted in pots containing fungal inoculum. Studied traits were concentrations of iron, zinc, manganese, and phosphorus in aerial parts. Concentrations of these elements were higher in the aerial parts of Ohadi pistachio seedlings treated with AMF than the fungi-free conditions with a significant difference at 5% level. Concentrations of all elements were higher in the aerial parts of AMF-treated Kalleghouchi seedlings than the non-inoculation conditions in sterile soil. Except iron, the other three elements were different significantly at 5% level. Overall, it was observed that AMF application increased the concentrations of iron, zinc, and manganese nutrients in aerial parts of both cultivars.

Keywords: Mycorrhiza, Phosphorus, Pistachio, Trace Elements.

Introduction

The area under pistachio cultivation in Kerman province is 296,000 hectares, with a production per unit area of 13 tons per hectare. The main cultivation areas include Kerman, Rafsanjan, Zarand, Sirjan, Anar, and Shahrebabak (Statistics of Agriculture-Jihad Organization, Kerman province). Fandoghi (Ohadi) cultivar, with 143,154 hectares (74.5%), accounts for the highest area under pistachio cultivation, comprising half of the total pistachio cultivation in Kerman, and Kalle-ghouchi cultivar is in the second place with 73,929 hectares (42.5%). The soils of the region are not acceptable in terms of available nutrients, such as

phosphorus and trace nutrients, due to an alkaline pH (7.5-4.4) and low organic matter. A group of mycorrhizae-forming fungi, such as vesicular and arbuscular species, are able to establish symbiosis with many plants, thereby increasing the growth and development of the host plant.

In the symbiosis, fungi was seen to receive organic carbon and other compounds from the host plant for its growth and development, and in return, provides the nutrients and water needed by the plant. This feature has a high value for the host plant, particularly under low soil fertility and environmental stresses. The symbiosis of fungi with plant roots was shown to increase the absorption of phosphorus, iron, zinc, and manganese in the plant. Mycorrhiza is a symbiosis between plant roots and fungi that plays an important role in the nutrient cycle of an ecosystem and protection of plants against environmental stresses (Iraqi et al., 2011).

Most plants have mycorrhizal symbiosis. Mycorrhizal fungi function preferentially in some plants and have a greater ability to reproduce on a specific host. Therefore, fungi differ from each other in terms of physiological effects and impacts on the growth of the host plant (Karami, 2017).

In the rhizosphere of pistachio trees, there are different types of soil organisms, such as arbuscular mycorrhizal fungi (AMF), making mutual symbiosis with the roots of trees (Jalali et al., 2011). Because pistachio trees produce fewer capillary roots, their growth is strongly dependent on the AMF (Iraqi et al., 2011). There is an obligate symbiosis between this plant and fungi hence AMF play a significant role in increasing the yield of pistachio trees, particularly in low fertility soils. It was found AMF could replace 30-60% of phosphorus fertilizer, increased zinc uptake in deficiency conditions, and generally amplified plant uptake under the deficiency of nutrients (Anith et al., 2011).

The first effect of AMF is an increase in the absorption of minerals in the plant, in particular elements that are present in soil solution in the form of slow-motion ions or at low concentrations (Abdllatif et al., 2009). (Mousavi et al., 2012) reported that mycorrhizal pistachios contained higher concentrations of phosphorus, potassium, zinc, and manganese than non-mycorrhizal pistachios regardless of soil moisture content, while copper and iron concentrations were not different in the plants. (Bagde et al., 2010) concluded that one of the reasons for the further growth of mycorrhizal plants in soils of arid regions is their ability to absorb water in the soil after the wilting point.

According to the above, mycorrhiza can play an important role in increasing the absorption and concentrations of nutrients in the plant. In this study, therefore, the effect of AMF was investigated on concentrations of some nutrients in Ohadi (Fandoghi) and

Kalle-ghouchi pistachios with the highest cultivated area.

Materials and Methods

This study was performed in a factorial pot experiment as a completely randomized design with two factors in three replications. The cultivar factor was applied at two levels (Ohadi or Fandoghi and Kolleghouchi cultivars) and culture medium at three levels (fungi-free non-sterile soil, fungi-free sterile soil, and sterile soil or fungal inoculation). Arbuscular fungal strain was obtained as mixed with sand from the biology department of Kerman Soil and Water Research Institute.

Preparation of soil sample

The soil used here was prepared from a depth of 0-30 cm in a field located in Sadatabad village, Kerman city. After complete drying in the open air, soil samples were passed through a 2 mm sieve. An amount of soil (5 kg) was poured into each disinfected plastic pot (depending on the medium factor type). To prepare sterile soil, required amount of soil was autoclaved at 120 °C for 1 h. (Table 1) represents some of measured the soil physical properties.

Table 1. Some physicochemical properties of the experimental soil

Soil texture	Absorbable K mg/kg	Absorbable P mg/kg	Organic C %	Soil reaction pH	EC (Ds/m)
Sand-loam	79	2.5	116	7.5	4.2

Seed sowing and inoculation

Before sowing, seeds of Fandoghi and Kolleghouchi cultivars were disinfected with 70% ethanol and 1% sodium hypochlorite for 2 min and 3 min, respectively, and then washed with distilled water. To facilitate fungal penetration, the sterilized seeds were placed at room temperature under vacuum for 1 h. In mycorrhizal treatments, about 3 cm of the top surface soil was removed from each pot, replaced by a layer of fungal sandy soil with a known weight of 100 g per pot, and the removed soil was then poured back into the pot.

Seeds were inoculated separately to prevent contamination of non-mycorrhizal pots. In each pot, the seeds were sown at a depth of 2-4 cm, and after their germination, the pots were maintained at 25 °C and each irrigated identically.

Measurement of nutrient concentrations in plant aerial parts

Concentrations of nutrients, viz. P, Fe, Zn, and Mn, were measured in the aerial parts of Fandoghi and Kolleghouchi pistachio cultivars. For this purpose, the plants were cut in the crown, and phosphorus concentration was measured by ammonium chromate method through spectrophotometry and concentrations of Fe, Zn, and Mn were determined by atomic absorption spectrometry in the aerial parts (Agha Babaei et al., 2011).

Statistical analysis

Data were analyzed using SAS software and means were compared using Duncan's multiple range test.

Results and Discussion

The alkaline pH of the soil in the region (Table 1) makes the uptake of nutrients in the plant difficult. Thus, AMF can effectively help the plant to absorb more nutrients. The results of ANOVA for the effect of planting medium were significant at the level of 1%. Significant differences were observed between Fandoghi and Kolleghouchi cultivars in terms of nutrient contents in the aerial parts. There was a significant interaction between culture medium and the cultivar with regard to nutrient contents. Different reactions were observed in the two species of pistachios (Table 2).

Table 2. ANOVA results of the traits studied in aerial parts

Sources of variance	df	P	Fe	Zn	Mn
Planting medium (A)	2	14634.6**	679.707**	58.6**	972.136 **
Species (B)	1	510.9**	6104.056**	273.724**	422.49**
AB	2	250.1**	436.992 **	36.30**	26.81**
Error	12	19.16	84.37	9.5	8.17
CV (%)		91.76	18.17	7.9	6.14

The results of comparing the mean of data in P nutrient were significant at the level of 5%, with Fandoghi cultivar containing the highest concentration of P in the aerial parts in the fungi-containing sterile medium (0.442 mg/kg). The lowest P concentration was measured in the aerial parts of Kolleghouchi cultivar in the fungi-free planting medium (0.153 mg/kg). In both sterile planting media (fungi-free and with fungal inoculation), P concentration in the aerial parts of Fandoghi cultivar was significantly higher than that of Kalleghouchi cultivar. In fungi-free non-

fungal planting medium, P content in the aerial parts Kalleghouchi cultivar was significantly higher than that of Fandoghi cultivar. It seems that the addition of fungi led to significant increases in P concentrations in the aerial parts of both Fandoghi and Kalleghouchi cultivars (Table 3).

(Nasiri, 2007) showed that the use of AMF could increase P concentrations in the aerial parts of trees. (Agha Babaei et al., 2011) reported that mycorrhiza increased P concentrations in the aerial parts almond tree and had different effects on different cultivars. (Yaqubian et al., 2012) stated that mycorrhizal and non-mycorrhizal plants would absorb equal amounts of mobile phosphorus from the soil, and the association of plant with mycorrhizal fungi provides better utilization of non-mobile phosphorus in the soil.

Comparison of mean concentrations of trace elements (Table 3) revealed that AMF increased Fe concentrations in the aerial parts of both Fandoghi and Kalleghouchi cultivars, with higher levels in the former than in the latter. Mean concentrations of Fe were not different significantly in mycorrhiza and non-mycorrhiza treatments. The comparison of means (Table 3) indicated that the aerial parts of Fandoghi cultivar contained the highest value (177.3 mg/kg) in the fungi-containing sterile medium, which was different significantly from that in the aerial parts of Kolleghouchi cultivar (131.2 mg/kg) in the fungi-free sterile medium.

Table 3. Comparison of average interactions of planting medium and cultivar on nutrient concentrations in the aerial parts

Planting medium (soil)	Species	Fe (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	P (mg/kg)
Fungi-free nonsterile	Kolleghouchi Fandoghi	128c 160ab	8.01c 15.200a	334.100c 615.200a	0.211b 0.177a
Fungi-free sterile	Kolleghouchi Fandoghi	131.200c 169ab	5.930c 11.100b	250c 512.100b	0.153b 0.192d
Fungi-containing nonsterile	Kolleghouchi Fandoghi	150.400b 177.300a	11.01b 15.450a	436.400b 667.200a	0.352b 0.442a

Means with similar letters in each column do not differ significantly at 5% level by Duncan's test.

Comparison of mean interactions on nutrient concentrations showed that the AMF-containing medium increased zinc concentrations in the plant aerial parts of both Fandoghi and Kolleghouchi cultivars (Table 3).

The comparison of mean Zn concentrations using Duncan's test was significant at the level of 5%. Accordingly, the highest (15.450 mg/kg) and the lowest (5.930 mg/kg) Zn concentrations were recorded in the aerial parts of Fandoghi and Kolleghouchi cultivars in fungi-containing and fungi-free sterile media, respectively. Zn concentrations were significantly higher in the aerial parts of Fandoghi cultivar in all planting media than those of Kolleghouchi cultivar (Table 3). It seems that the presence of AMF can increase Zn concentrations by 20-30% in the aerial parts. (Mousavi et al., 2012) detected that AMF could provide up to 20% of Zn required by plants.

Based on the comparison of means, Mn concentrations were uppermost (667.2 mg/kg) in the aerial parts of Fandoghi cultivar in the fungi-containing sterile planting medium, and the lowest value (250 mg/kg) was observed in Kolleghouchi cultivar in the fungi-free sterile planting medium. Mn concentrations were significantly higher in the aerial parts of Fandoghi cultivar than those of Kolleghouchi cultivar in all the media (Table 3). It can, therefore, be concluded that the presence of AMF increased Mn concentrations in the aerial parts of both plants, but Fandoghi cultivar contained higher Mn levels than Kolleghouchi cultivar. According to the results, AMF can reproduce well in the roots of both Fandoghi and Kolleghouchi cultivars and have a good compatibility with the study area, which can be effective in the uptake of more nutrients in different cultivars of pistachio plant. Further studies on other cultivars and fungal strains and their effects on plant characteristics can be effective in the development of agriculture in the region and its introduction to farmers.

Conclusion

Overall, the results show that the presence of AMF can be effective in the uptake and elevation of nutrient concentrations in different cultivars. Considering the climate and the alkaline soil of the region seem to make the uptake and availability of nutrients to the plant difficult when necessary. It is, therefore, recommended to pay more attention to Fandoghi cultivar with more cultivated area in the region. The use of AMF can significantly reduce the use of chemical fertilizers while absorbing nutrients and also play an important role in terms of sustainable agriculture and environmental factors.

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