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Arbuscular mycorrhizal colonization can improve plant yield in cropping systems

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ABSTRACT

To investigate the influence of Arbuscular mycorrhizal (AM) fungi on dill and common bean yield at different cropping systems in 2013, an experiments was carried out with factorial arrangement based on randomized complete block design with three replications. The factors were cropping systems including a) common bean (*Phaseolus vulgaris* L.) sole cropping (40 plants m^{-2}), b) dill (*Anethum graveolens* L.) sole cropping at different densities (25, 50 and 75 plants m^{-2}) and c) the additive intercropping of common bean + dill (25+40, 50+40 and 75+40 plants m^{-2}). All these treatments were applied with (+AM) or without (-AM) AM colonization. The AM colonization significantly increased the plant height, root depth and seed yield as compared to non-inoculated plants. Intercropping significantly changed plant height, root depth and seed yield compared to sole cropping. Seed yield and plant height for intercrops were higher than those for sole crops.

Key Words: Arbuscular mycorrhizal, Intercropping System, Plant density, Seed yield.

INTRODUCTION

Intercropping is an old and widespread practice used in low input cropping systems in many areas of the world (Anil et al. 1998). Depending on plant species, region and climate, intercropping can increase total yield per land area compared to the sole crop of the same crops, because intercropping makes better use of one or more agricultural resources in both space and time (Willey 1990; Rodrigo et al. 2001). The advantages of intercropping have been demonstrated in numerous systems (Ghosh 2004). Such improvements in yield have been attributed almost exclusively to above-ground interactions between intercropped species, for example greater interception of sunlight or more efficient conversion of the intercepted radiation. However, yield advantages of intercropping systems are due to both above- and below-ground interactions between intercropped species (Li et al. 2006).

Dill (*Anethum graveolens* L.) is an important essential oil bearing plant of Iran. The essential oils from its fruits and shoots have found application in the food pharmaceutical, and soap industries. It is well accepted that adequate use of irrigation and chemical fertilizers improve yield and the quality of oil in aromatic plants (Singh & Randhawa 1990; Tiwari & Banafar 1995).

The arbuscular mycorrhiza (AM) play an important role in nature. AM are the most important microbial symbioses for the majority of plants and, under conditions of P-limitation, influence plant community development, nutrient up- take, water relations and above-ground productivity (Das & Varma 2009).

However, it was recently reported that *Funneliformis mosseae* directly increases the essential oil content in shoots of *Origanum* sp. (Khaosaad et al. 2006) as well as sweet basil (Copetta et al. 2006). The aims of the present study was to evaluate the effects of mycorrhization by *F. mosseae* and cropping systems on AM colonization, plant height, root depth and seed yield of dill and common bean.

MATERIALS AND METHODS

Experimental design

Two field experiments were conducted in the Agriculture and Natural Resources Research Center of Kurdistan Province in 2013. Soil samples (from 10 – 15 cm depth) were collected in 2013 from 8 points using a soil auger. All soil samples were air dried at laboratory for 3 days and then crushed and sieved through a 2 mm sieve. The experiments were carried out with a factorial arrangement based on randomized complete block design with three replications. The factors were cropping systems including: a) common bean (*Phaseolus vulgaris* L.) sole cropping (C40 = 40 plants m^{-2}), b) dill (*Anethum graveolens* L.) sole cropping at different densities (D25, D50 and D75: 25, 50 and 75 plants m^{-2}, respectively) and c) the additive intercropping of dill + common bean (25+40, 50+40 and 75+40 plants m^{-2}). All these treatments were applied with (+AM) or without (-AM) arbuscular mycorrhiza colonization.

The crops were managed according to organic farming practices without pesticide or fertiliser use. No mechanical weeding was performed after sowing. The inoculum consisted of colonized root fragments, sand, AM hyphae, and spores. The inoculum was mixed with an inert material for dilution and homogenizing the distribution in the soil. A 30-g portion of inoculum was added to each plot (4m×5m) at sowing time just below the seeds. The arbuscular mycorrhiza fungi (*Funneliformis mosseae*) was obtained from the University of Tabriz, Iran.

Arbuscular mycorrhiza colonization

The root samples were extracted by using a cylindrical corer (10 mm). The soil was removed by soaking the roots in water and gently washing them, to ensure that all the thinner roots and tips remained intact. The staining procedure was applied according to Vierheilig et al. (2005) with the modified parameters for the present study. The roots were cut into small pieces (1 cm) and placed in a beaker (10% KOH) for 60 min in a water bath at 65°C. The roots were then rinsed with tap water and acidified with 5% lactic acid at room temperature for 12 h. Finally, the roots were stained by a solution containing 875 ml lactic acid, 63 ml glycerin, 63 ml tap water and 0.1 g acid fuchsin for 30 min at 70°C and then de-stained in laboratory by lactic acid for 15 min. Ten root segments were mounted onto slides and examined at 100-400 magnification under a Nikon YS100 microscope. Beneath the glass slide an acetate film with 10 thin lines was adapted. At crossing points between roots and lines, each point that had an infection was recorded and the number of infections was expressed as percentage. The percentage of mycorrhizal root colonization was calculated as (McGonigle et al, 1990).

Statistical analysis

Combined analysis of variance was performed using SAS version 9.1 (SAS Institute Inc., Cary, NC, USA) (SAS Institute Inc. 1988). Means of the treatments were compared, using Generalized Linear Model (GLM) method and the least significant difference (LSD) test at the 5% probability level. The data showed normal distribution and no transformation was required.

RESULTS AND DISCUSSION

Arbuscular mycorrhizae colonization

AM was observed in all plant species and root samples. The percentage of mycorrhizal root colonization was significantly ($P \leq 0.01$) greater in all the mycorrhizal treatments than in the non-inoculated controls. There were no significant differences in colonization rates of sole and intercropping systems (Fig. 1).

Plant height

Dill plant height was affected by AM colonization and different cropping systems, so that the inoculated plants with *F. mosseae* had more, but non-inoculated plants had less plant height (Fig. 2). Plant height was significantly influenced by cropping systems. Dill + common bean intercropping increased plant height compared with sole crops (Fig. 3).

Previous our studies have shown that different species and isolates of *Glomus* increased plant height, total dry weight and root and shoot dry weights of chickpea (Sohrabi et al. 2012a, b).

Root depth

Dill root depth was significantly influenced by AM colonization. So, the root colonization with AM significantly increased root depth of dill (Fig. 4). The root depth intercropped plants decreased

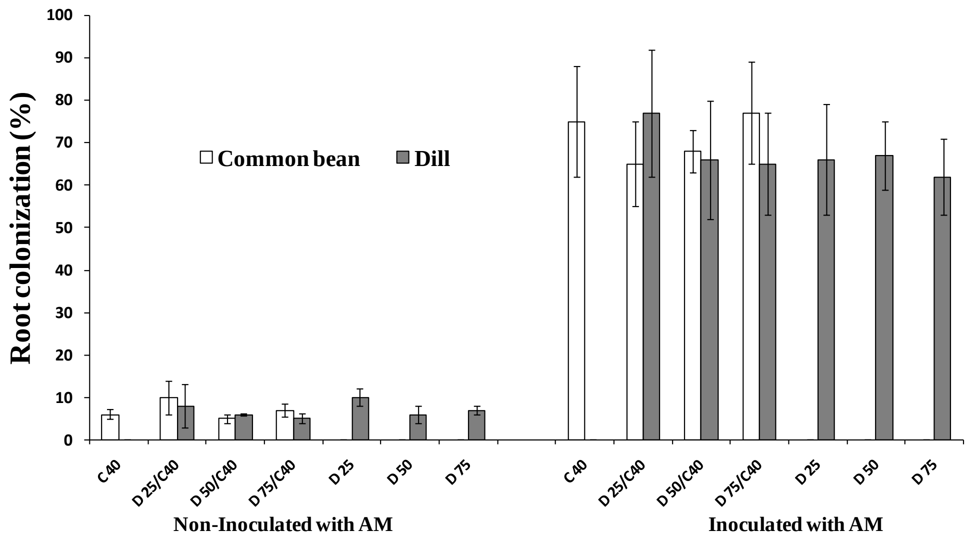

Fig 1. Root colonization percentage in common bean and dill under sole and intercropping systems inoculated and non-inoculated with arbuscular mycorrhizal fungus (*Funneliformis mosseae*). Means± S.D., $P < 0.05$.
C40: sole cropping of common bean (40 plants m^{-2}).
D25, D50 and D75: sole cropping of dill at 25, 50 and 75 plants m^{-2}, respectively.
D/C: dill+common bean intercropping.

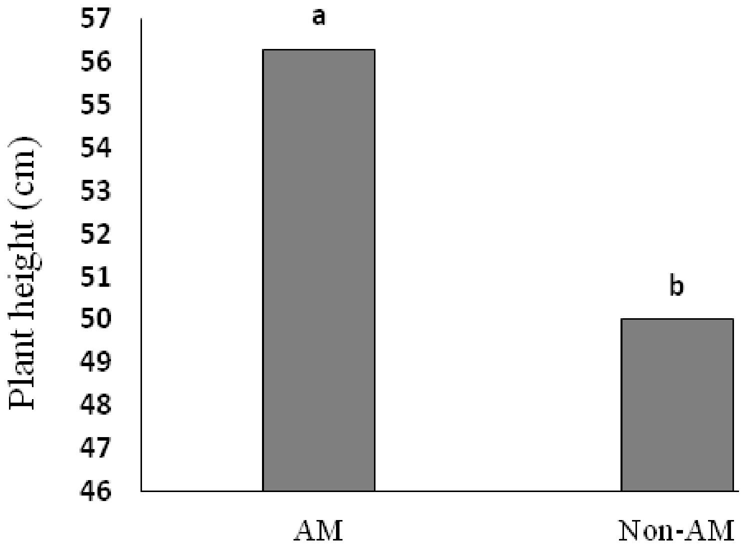

Fig 2. Plant height of dill inoculated (AM) and non- inoculated (Non-AM) with arbuscular mycorrhiza (*Funneliformis mosseae*) in 2013. Results are the mean of three replications ±SD. $P < 0.05$.

(D25/C40, D50/C40) by intercropping, compared with the sole cropping (D25, D75) (Fig. 5).

Improvement of growth parameters in plants inoculated with AM fungi can be related to ability of AM fungi in increasing the water absorption capacity of plant by increasing root hydraulic conductivity, the absorptive surface area of the root system, and access to small soil pores (Augé 2001).

Seed yield

Root colonization with AM significantly increased seed yield of dill and common bean. Seed yield of dill and common bean was higher with AM colonization combated with non- AM colonization (Fig 6). Seed yield was significantly influenced by cropping systems. Dill + common bean intercropping (D50+C40 and D75+C40) increased seed yield of dill compared with sole crops (D25) (Fig. 7). Furthermore, seed yield of common bean was higher under intercropping than under sole cropping systems, so that common bean increased

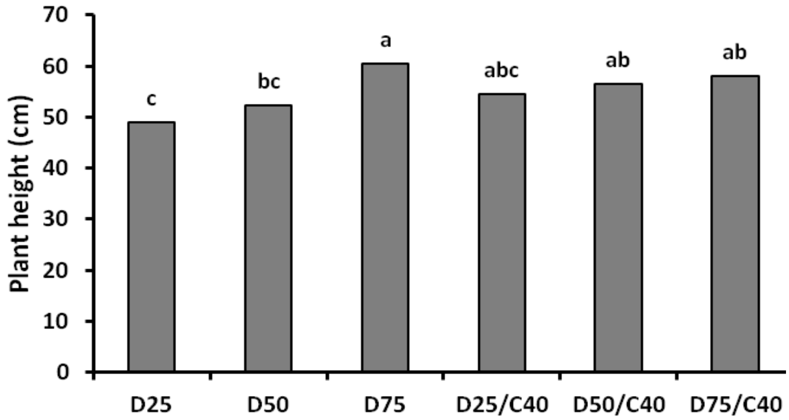

Fig. 3. Plant height of dill at different cropping systems in 2013. Results are the mean of three replications ±SD. *P < 0.05.*
D25, D50 and D75: sole cropping of dill at 25, 50 and 75 plants m^{-2}, respectively.
D/C: dill + common bean intercropping.

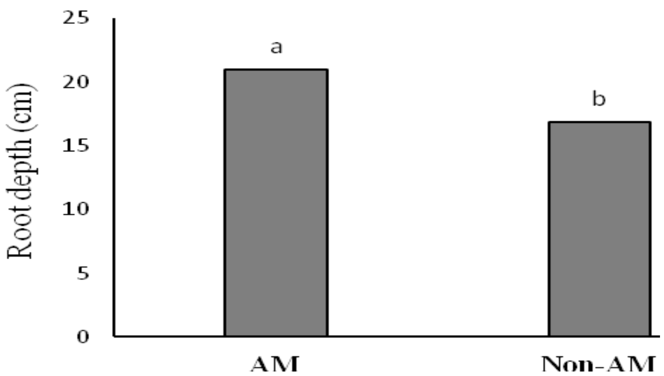

Fig 4. Root depth of dill inoculated (AM) and non- inoculated (Non-AM) with arbuscular mycorrhiza (*Funneliformis mosseae*) in 2013. Results are the mean of three replications ±SD. *P < 0.05.*

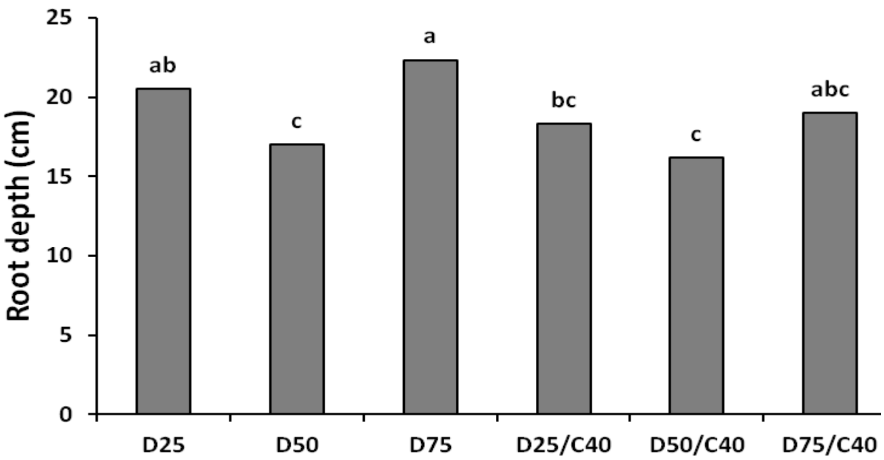

Fig. 5. Root depth of dill at different cropping systems in 2013. Results are the mean of three replications ±SD. P < 0.05.
D25, D50 and D75: sole cropping of dill at 25, 50 and 75 plants m^{-2}, respectively.
D/C: dill + common bean intercropping.

in dill + common bean intercropping (D25+C40 and D50+C40), compared to sole cropping (C40) (Fig. 8).

Legume crops such as common bean, thanks to symbiotic fixation of atmospheric nitrogen, may alleviate soil nitrogen restrictions of accompanying non-legume crops, which may consequently improve the overall productivity (Vandermeer 1989). Studying oregano and mint, Karagiannidis et al. (2011) it was found that the dry mass of AM inoculated plants increased from 2 to 4.7 fold when compared with non-inoculated plants. The same was observed by Khaosaad et al. (2006).

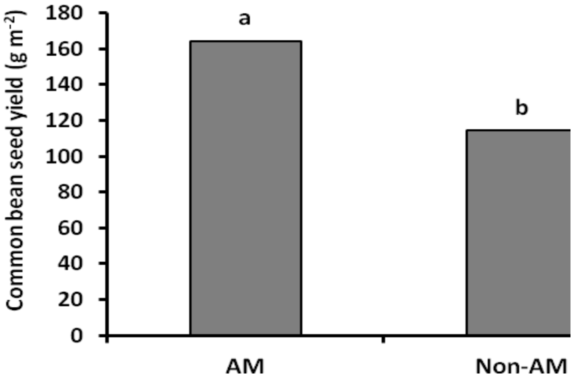

Fig 6. Seed yield of common bean inoculated (AM) and non- inoculated (Non-AM) with arbuscular mycorrhiza (*Funneliformis mosseae*) in 2013. Results are the mean of three replications ±SD. $P < 0.05$.

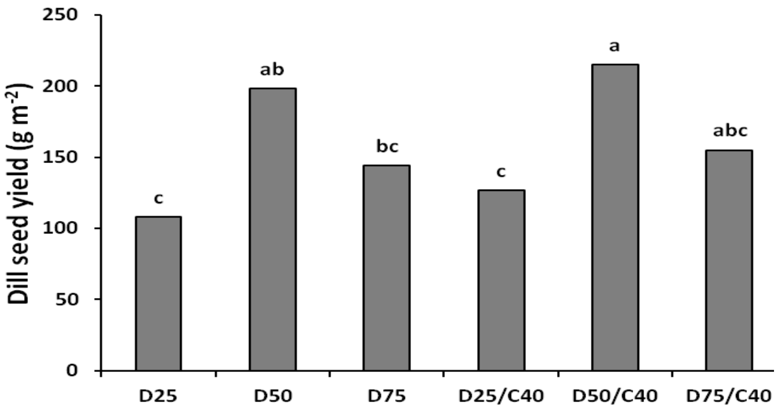

Fig. 7 Seed yield of dill at different cropping systems in 2013. Results are the mean of three replications ±SD. $P < 0.05$.

D25, D50 and D75: sole cropping of dill at 25, 50 and 75 plants m^{-2}, respectively.

D/C: dill + common bean intercropping.

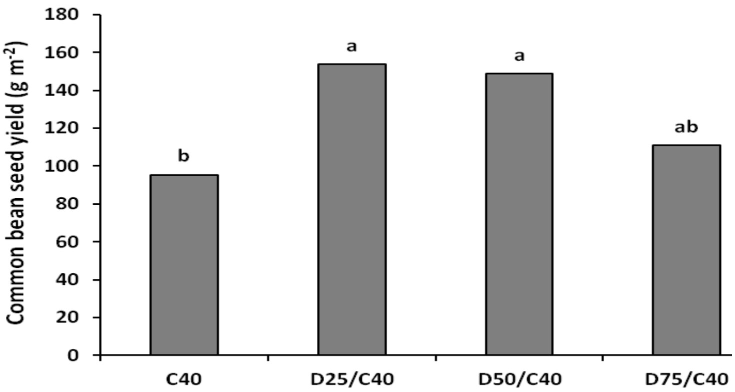

Fig. 8 Seed yield of common bean at different cropping systems in 2013. Results are the mean of three replications ±SD. $P < 0.05$.

C40: sole cropping of common bean (40 plants m^{-2}).

D/C: dill + common bean intercropping.

CONCLUSION

Intercropping system and AM fungi influenced plant height, root depth and seed yield. Intercropping of common bean and dill with AM colonization showed a yield advantage compared with sole cropping of non- inoculated plants.

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