

## **Growth Response of Two Species of *Zizyphus* to Inoculation with Arbuscular Mycorrhizal Fungi**

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*Abstract.* Responses of two *Zizyphus* species of (*Zizyphus spina-christi* L. and *Z. nummularia* Burm.f.) to inoculation with and without arbuscular mycorrhizal fungi were investigated in a greenhouse over a 12 weeks period. Mycorrhizal inoculation significantly increased the biomass, root development (volume, surface area, diameter and number of tips), and photosynthetic pigments of both species in comparison to non-mycorrhizal plants. Such increases were related to the intensity of mycorrhizal infection in the root. *Z. spina-christi* was found to be more dependent on mycorrhizal fungi for its growth than *Z. nummularia*. These findings indicate that mycorrhizal inoculation can be a suitable way (biofertilizer agents) to improve growth and root development of tropical *Zizyphus* plants, particularly in poor soils.

### **Introduction**

Mycorrhizae represent a symbiotic association between beneficial soil fungi and plant roots (Smith and Read, 1997). This symbiosis is characterized by a bidirectional movement of nutrients, where carbon flows to the fungus, and inorganic nutrients move to the plants (Abdel-Fattah, 2001). This is largely due to external hyphae absorbing poorly mobile soil nutrients beyond the depletion zones, around roots and root hairs, and transporting them to root tissues of their host, leading to improved plant growth and reproduction (Abdel-Fattah, 1997; Olsen *et al.*, 1999; and Okurowska, 2008).

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Arbuscular mycorrhizal (AM) fungi are ubiquitous in natural ecosystems, associating with about 80% of the terrestrial plant species (Smith and Read, 1997, Agwa and Abdel-Fattah, 2002, Besserer *et al.*, 2008 & Wang and Shi, 2008). They are recognized as important, widespread components of most terrestrial ecosystems, benefiting plant establishment by enhancing plant nutrient acquisition, improving soil quality and increasing resistance to environmental stresses (Abdel-Fattah *et al.*, 2002, Al-Qarawi, 2002, Al-Karaki *et al.*, 2004, Andrade *et al.*, 2008 & Wang *et al.*, 2008) and also playing an important role in plant biodiversity, ecosystem variability and productivity (Likar *et al.*, 2008).

*Zizyphus spina-christi* is an important native species in Saudi Arabia. The genus belongs to the family Rhamnaceae, which includes 40 species. *Z. spina-christi* is an indigenous tree of the Arabian Peninsula; it grows wild throughout the country, but in high density in the Southern and South-western regions of Saudi Arabia (Said, 1986). Leaves of this species are a source of medicinal compounds used for managing several ailments by the indigenous population (Zoghet and Alsheikh, 1999 & Weinges & Schick, 1995). It is used for its cleaning properties and is a staple food for animals. The leaves contain flavonoids (Nawwar *et al.*, 1984 and Gupta & Mehta, 2000), saponin, alkaloids, and other potentially allelochemical substances that may be important in the interaction between *Z. spina-christi* and other plant species. Increased growth and yield of *Zizyphus* plants in the presence of arbuscular mycorrhizal infection has been attributed mainly to the enhanced uptake of soil nutrients like phosphorus (Guissou *et al.*, 1998 & 1999 & Ba *et al.*, 2001). *Glomus constrictum* Trappe significantly improved the biomass production and nutrient uptake of *Zizyphus mauritiana* grown in the field, as compared with non-mycorrhizal plants (Mathur and Vyas, 1995 and 1999; & Kale and Dod, 2000).

Naturally, mycorrhizal fungi play a key role in the natural and agricultural ecosystems through major functions. However, little is known about the ecology and functional role of mycorrhizal fungi in woody plants in Saudi Arabia. The present investigation was therefore undertaken to study the effect of arbuscular mycorrhizal (AM) inoculation on the growth and root development of two species of *Zizyphus* (*Z. spina-christi* L. and *Z. nummularia* Burm.f.) grown under the greenhouse conditions.

## Materials and Methods

### *Plant and Growth Conditions*

Seeds of *Zizyphus spina-christi* L. and *Zizyphus nummularia* Burm. plants were surface sterilized in Clorox 12° for 15 min, subsequently rinsed with sterilized water and left to germinate for 7 days in moist sterilized filter paper. Uniform seedlings were planted (one plant/ tube) into sterilized plastic tubes containing loamy soil collected from Durab farm, College of Food and Agricultural Sciences, King Saud University. Half of the tubes for each plant species containing soil were left without sterilization to serve as mycorrhizal treatments. The mycorrhizal inoculum consisted of spores of *Glomus mosseae* and *Glomus monosporum* (620 spores/ 100g). Each individual plant received 600g inoculums for inoculation treatments. The mycorrhizal fungi were originally from Durab farm, Saudi Arabia and were identified by G. M. Abdel-Fattah, Applied Mycology Dep., King Saud University. The non-mycorrhizal treatment received filter leachates (1 ml/ plant) of the mycorrhizal inoculum to provide mycorrhiza-associated microorganisms other than mycorrhizal propagules. The filtrate was passed through a 25- $\mu$ m sieve to remove spores of mycorrhizal fungi. All tubes were randomized in a growth chamber under controlled conditions (280  $\mu$ mol  $m^{-2}s^{-1}$ , 22/18 °C, 16 h photoperiod, 70-80% relative humidity). All plants received 10% Hoagland solution minus phosphorus (Hoagland and Arnon, 1950). Ten plants for each treatment were harvested at 12 weeks after planting.

### *Measurements*

Fresh and dry masses of shoots and roots were determined immediately after harvest. Also, the shoot height was measured. For each treatment, the whole root system was washed carefully in tap water to remove the adhering soil particles, and stained with salt. Root system (six replicate plants for each treatment) was gently spread on Scanner (UMAX, Astra 4000 U) for analysis of root morphology (length, diameter, volume and tips) by using WinRhizo software (Regent Instruments, Quebec, Canada).

### ***Staining of Mycorrhizal Root***

Immediately after harvest, the root system was cut into small segments (5– 10mm). Randomly chosen root segments were cleared in 7% potassium hydroxide at 90 °C for 45 min, stained with trypan blue in lactophenol (Phillips and Hayman, 1970) for 15 min at 90 °C. The excess stain was removed by washing with tap water. Forty randomly selected root pieces were mounted on slides in lactoglycerol, squashed, and examined microscopically (Leitz Wetzlar, Germany).

### ***Estimation of Mycorrhizal Infection***

The levels of mycorrhizal infection were estimated by the method of Trouvelot *et al.* (1986), which calculates three parameters of infection, namely, frequency of root infection (F), intensity of cortical root infection (M) and arbuscule frequency in roots (A).

### ***Estimation of Photosynthetic Pigments***

Plant photosynthetic pigments (chlorophyll a and chlorophyll b) were determined by the spectrophotometric method recommended by Porra *et al.* (1989). A known fresh weight of leaves was extracted in 5ml of dimethylformamide and left overnight in refrigerator. The filtered extract was measured against a blank of pure solvent at 2 wave lengths of 663.8 and 646.8 using Ultrospec 2000– UV/ Visible spectrophotometer. The contents of chlorophyll a and chlorophyll b and total chlorophyll (a + b) were calculated using the following formulae and expressed in nanomoles per milliliter:

$$\begin{aligned}\text{Chl } a &= 13.43 A^{663.8} - 3.47 A^{646.8} \\ \text{Chl } b &= 22.90 A^{646.8} - 5.38 A^{663.8} \\ \text{Chl } a + b &= 19.43 A^{646.8} - 8.05 A^{663.8}\end{aligned}$$

Mycorrhizal dependency (MD) was calculated by the following equation: Values of mycorrhizal plants – values on non-mycorrhizal plants/ values on mycorrhizal plants ×100.

### ***Experimental Design and Statistical Analysis***

A factorial experiment in completely randomized design was carried out, to study the effects of two mycorrhizal treatments on two species of *Zizyphus* (*Z. spina-christi* L. and *Z. nummularia* Burm.), four

treatments were repeated 10 times, this comprising a total of 40 plastic tubes (50 cm × 5 cm), which were distributed randomly in a greenhouse under controlled conditions. The obtained data were statistically analyzed using the analysis of variance procedures, then means were compared by the least significant difference (LSD) method according to El-Nakhlawy (2009) using the SAS (SAS, 2005).

## Results and Discussion

### *Growth Responses*

Mycorrhizal inoculation resulted in a significant increase in shoot height and dry mass of the two species of *Zizyphus*, as compared with equivalent non-inoculated control plants (Table 1). Such increases in these parameters were linked with the degree of mycorrhizal infection. In this connection, increases in shoot height, shoot dry weight and root dry weight in response to the beneficial effects of the mycorrhizal fungi were positively correlated ( $r = 0.730$ ,  $0.862$  and  $0.669$  respectively for *Z. spina-christi*, while  $r = 0.988$ ,  $0.903$  and  $0.744$  respectively for *Z. nummularia*) to the intensity of mycorrhizal infection (Table 2).

*Zizyphus spina-christi* and *Z. nummularia* are important native species in Saudi Arabia, and carry enough economic and medicinal importance. The present data show that, regardless of the type of species, mycorrhizal inoculation enhanced the growth of *Zizyphus* plants in comparison with non-mycorrhizal plants. Such increases in growth responses were related to the degree of mycorrhizal infection for each plant species. The most prominent contribution of these mycorrhizal fungi to plant growth is mainly due to the uptake of phosphorus and other elements by extraradical mycorrhizal hyphae and transference to the root tissues (Abdel-Fattah, 1997, Guissou *et al.*, 1998, Mathur and Vyas, 1999 and Wang *et al.*, 2008). Our observations agree with those of Guissou, *et al.* (1999) who found that infection of *Zizyphus mauritiana* by vesicular-arbuscular mycorrhizal fungi resulted in a greater absorption of P and N as compared with non-mycorrhizal plants. Mathur and Vyas (1995) reported that *Glomus deserticola* improved the biomass production, nutrient uptake and acclimatization of the produced plantlets of *Zizyphus mauritiana* in pots under green house conditions.

**Table 1. Effect of mycorrhizal inoculation on growth responses and root morphology of two species of *Zizyphus*. Values are the means  $\pm$  SE.**

Growth parameters	<i>Z. spina-christi</i>		<i>Z. . nummularia</i>		LSD (0.05)
	- M	+ M	- M	+ M	
Shoot dry weight (g)	0.258 $\pm$ 0.013	0.40 $\pm$ 0.039	0.079 $\pm$ 0.007	0.245 $\pm$ 0.039	0.094
Root dry weight (g)	0.181 $\pm$ 0.009	0.296 $\pm$ 0.063	0.098 $\pm$ 0.022	0.163 $\pm$ 0.019	0.115
Root / shoot ratio	0.704 $\pm$ 0.061	0.724 $\pm$ 0.083	0.098 $\pm$ 0.023	0.163 $\pm$ 0.019	0.464
Shoot height (cm)	14.16 $\pm$ 0.017	18.50 $\pm$ 2.02	9.67 $\pm$ 0.044	17.67 $\pm$ 0.441	3.46
Number of root tips	885 $\pm$ 31.1	2021 $\pm$ 17.5	247 $\pm$ 47.0	184 $\pm$ 49.9	219.8
Root volume (ml)	0.566 $\pm$ 0.092	0.980 $\pm$ 0.140	0.653 $\pm$ 0.123	0.587 $\pm$ 0.092	0.371
Root length (cm)	275 $\pm$ 72.5	543 $\pm$ 32.9	190 $\pm$ 9.73	203 $\pm$ 46.2	150.9
Root diameter (cm <sup>2</sup> )	0.499 $\pm$ 0.027	0.459 $\pm$ 0.018	0.656 $\pm$ 0.077	0.614 $\pm$ 0.019	0.140
Root surface area (cm <sup>2</sup> )	45.4 $\pm$ 11.0	83.83 $\pm$ 7.94	38.64 $\pm$ 7.46	39.00 $\pm$ 3.57	25.9

-M, non-mycorrhizal treatments, +M, mycorrhizal treatments

Root dimensions (length, diameter, volume, surface area and tips) of mycorrhizal *Z. spina-christi* were significantly larger than those of non-mycorrhizal plants. This increase in root parameters in response to mycorrhizal effects was positively correlated ( $r = 0.860$  for length,  $0.776$  for volume and  $0.877$  for tips, Table 2) to the degree of mycorrhizal infection. On the other hand, there were no significant differences in root parameters between mycorrhizal and non-mycorrhizal *Z. nummularia* plants (Table 1).

**Table 2. Values of correlations coefficients ( $r$ ) between intensity of mycorrhizal infection (M %) and mycorrhizal dependency (MD)<sup>1</sup> for several parameters of two species of *Zizyphus*.**

Parameters	$r$	
	<i>Z. spina-christi</i>	<i>Z. . nummularia</i>
Shoot dry weight	0.862**	0.903**
Root dry weight	0.669*	0.744**
Shoot height	0.730**	0.988**
Number of root tips	0.877**	- 0.416
Root length	0.860**	0.130
Root volume	0.776**	0.687*
Chlorophyll a	0.986**	0.917**
Chlorophyll b	0.939**	0.733**
Total chlorophyll	0.983**	0.904**

\* $P = 0.05$ , \*\* $P = 0.01$

(MD)<sup>1</sup> =  $(M - NM) / NM \times 100$ , where M is parameter value of mycorrhizal plants and NM is parameter value of non-mycorrhizal plants.

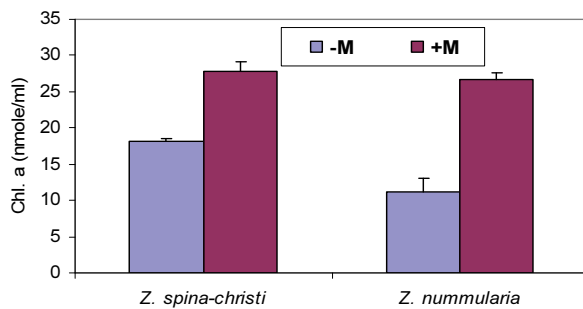
It is evident from the present study that root characters (total length, volume, diameter, surface area and tips) were greatly increased with inoculation by mycorrhizal fungi, compared with non-mycorrhizal treatments particularly in *Zizyphus spina-christi* plants. In another study, the density and length of root hairs of *Z. mauritiana* were positively correlated to mycorrhizal dependency (Guissou *et al.*, 1998). These results substantiate the earlier observations that stimulation of root system is enhanced by VA-mycorrhizal infection (Khudairi, 1969, Bagayoko *et al.*, 2000, Abdel-Fattah, 2001 & Bernatchez *et al.*, 2008). No significant difference was observed in the root to shoot dry mass ratio between mycorrhizal and non-mycorrhizal *Z. spina-christi* plants (Table 1). In contrast, this ratio was significantly higher in mycorrhizal *Z. nummularia* than in the non-mycorrhizal plants.

### **Photosynthetic Pigments**

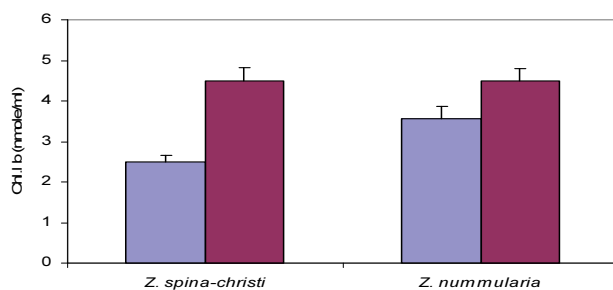
The contents of photosynthetic pigments (chlorophyll *a*, chlorophyll *b* and total chlorophyll *a + b*) in leaves of the two species of *Zizyphus* mycorrhizal plants were significantly ( $p = 0.05$ ) greater than those in equivalent non-mycorrhizal plants (Fig. 1). Such increases of their content were related to the degree of mycorrhizal infection. The increase in total chlorophyll (*a + b*) in response to mycorrhizal effects was positively correlated ( $r = 0.983$  and  $0.904$  for two species of *Zizyphus* respectively, Fig. 1).

### **Mycorrhizal Root Infection**

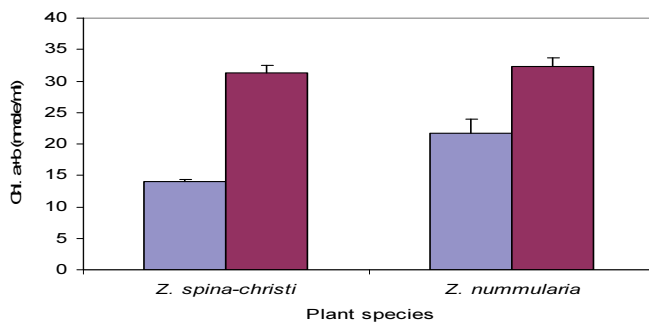
The levels of root infection by mycorrhizal fungi are expressed in Table 3, as frequency of mycorrhizal root infection (F %), intensity of mycorrhizal infection in the root tissues (M %) and rate of arbuscular formation in root segments (A %). The first gives an estimate of the rate of fungal colonization from the soil and of growth within the root, the second indicates the extent of colonization by the mycorrhizal fungi relative to root growth, whereas the third illustrates the rate of arbuscular (site of nutrient exchange between fungus and host plant) development. The levels of mycorrhizal infection in stained root segments of *Z. spina-christi* were significantly higher than root segments of *Z. nummularia*. No mycorrhizal colonization was observed in non-mycorrhizal plants of two species.



(A)



(B)



(C)

**Fig. 1.** Effect of mycorrhizal inoculation on the content of photosynthetic pigments {(A) chlorophyll a, (B) chlorophyll b and (C) total chlorophyll a +b} of two species of *Zizyphus*. Values are the means of three replicates. Error bars are SE. Where, -M: non – mycorrhizal treatments, +M: mycorrhizal treatments.



**Table 3. Levels of mycorrhizal infection of two species of *Zizyphus*. Values are the means  $\pm$  SE of three replicates.**

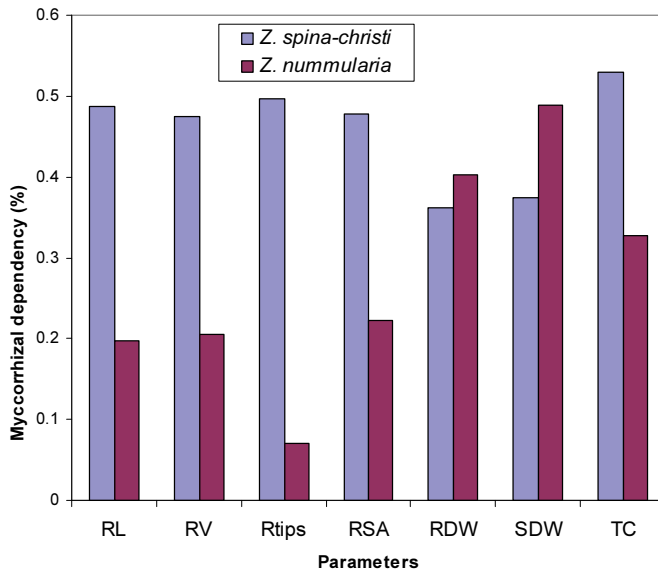
Parameters	<i>Z. spina-christi</i>		<i>Z. nummularia</i>	
	- M	+ M	- M	+ M
Frequency of mycorrhizal infection (F %)	0.0	68.33 $\pm$ 7.26	0.0	51.67 $\pm$ 1.67
Intensity of root cortical infection (M %)	0.0	5.18 $\pm$ 1.52	0.0	2.77 $\pm$ 0.801
Frequency of arbuscular development in roots (A %)	0.0	1.18 $\pm$ 0.566	0.0	0.460 $\pm$ 0.111

-M, non-mycorrhizal treatments, +M, mycorrhizal treatments

### *Mycorrhizal Dependency and Intensity of Infection*

Figure 2 shows that there was a close relation between mycorrhizal infection and the mycorrhizal dependency in the species studied.

In most cases, as the mycorrhizal infection increased, the rate of mycorrhizal dependency in plant growth and photosynthetic pigments was highly stimulated. In general, *Z. spina-christi* was greatly dependent on mycorrhizal fungi for the growth and development as compared with the *Z. nummularia* (Fig. 2).



**Fig. 2. Mycorrhizal dependency (MD %) of two plant species of *Zizyphus* for their growth, where: RL (root length), RV (root volume), R tips (number of root tips), RSA (root surface area), RDW (root dry weight), SDW (shoot dry weight) and TC (total pigments).**

## Conclusion

The results obtained here concluded that mycorrhizal inoculation can be a suitable way (biofertilizer agents) to improve growth and root development of tropical *Zizyphus* plants, particularly in poor soils. Farmers should be aware of the beneficial effects of mycorrhizae (biofertilizer agents) on plant growth and yield. Practical applications of these fungi are now possible, but these should bear in mind the factors (formulation, type of applications, viability of spores, ... *etc*) affecting mycorrhizal development and function. Further studies should be carried out in this field.

## References

- Abdel-Fattah, G.M.** (1997) Functional activity of VA-mycorrhizal fungus (*Glomus mosseae*) in the growth and productivity of soybean plant growing in sterilized soil, *Folia Microbiol.*, **5**: 495-502.
- Abdel-Fattah, G.M.** (2001) Measurement of the viability of arbuscular mycorrhizal fungi using three different strains; relation to growth and metabolic activities of soybean plants, *Microbiological Research*, **156**: 359-367.
- Abdel-Fattah, G.M., Meghaed, F.F. and Ibrahim, A.H.** (2002) Interactive effects of the endomycorrhizal fungus (*Glomus etunicatum*) and phosphorus fertilization on growth and metabolic activities of broad bean under drought stress, *Pakis. J. Biol. Sci.*, **5**: 853-861.
- Agwa, H.E. and Abdel-Fattah, G.M.** (2002) Arbuscular mycorrhizal fungi (Glomales) in Egypt. II- An ecological view of some deltaic Mediterranean coastal land, *Acta Botanica Hungarica*, **44**: 1-17.
- AL-Karaki, G.N., McMichael, B. and John, Z.** (2004) Field response of wheat to arbuscular mycorrhizal fungi under drought stress, *Mycorrhiza*, **14**: 263-269.
- Al-Qarawi, A.A.** (2002) Relationships Among Nitrogen Availability, Vesicular-Arbuscular Mycorrhizae, and *Bromus tectorum* in Disturbed Rangeland Sites in Colorado, *Ph.D. Dissertation*, Colorado State Univ. Fort Collins, CO. USA.
- Andrade, S. A. L., da Silveira, A. P. D., Jorge, R. A. and de Abreu, M. F.** (2008) Cadmium accumulation in sunflower plants influenced by arbuscular mycorrhiza, *Internat. J. Phytoremediation*, **10**: 1-13.
- Aseri, G. K., Jain, N., Panwar, J., Rao, A. V. and Meghwal, P. R.** (2008) Biofertilizers improve plant growth, fruit yield, nutrition, metabolism and rhizosphere enzyme activities of pomegranate (*Punica granatum L.*) in Indian Thar Desert, *Scientia Horti.*, **117**: 130-135.
- Azcon, R., Gomez, M. and Tobar, R.** (1992) Effects of nitrogen sources on growth nutrition, photosynthetic rate and nitrogen metabolism of mycorrhizal and phosphorus-fertilized plants of *Lactuca sativa L.*, *New Phytol.*, **121**: 227-231.
- Ba, A. M., Plenchette, C., Danthu, P., Duponnois, R. and Guissou, T.** (2001) Functional compatibility of two arbuscular mycorrhizae with thirteen fruit trees in Senegal, *System. J.*, **50**: 95-105.

- Bagayoko, M., George, E., Romheld, V. and Buerkert, A.** (2000) Effects of mycorrhizae and phosphorus on growth and nutrient uptake of millet, cowpea and sorghum on a west African soil, *J. Agric. Sci.*, **135**: 399-407.
- Bernatchez, F., Jeannotte, R., Begg, C.B.M., Hamel, C. and Whalem, J.K.** (2008) Soil fertility and arbuscular mycorrhizal fungi related to stress growing on small holder farms in Senegal, *Journal of Arid Environments*, **72**: 1247-1256.
- Besserer, A., Becard, G., Jauneau, A., Roux, C. and Sejalon-Delmas, N.** (2008) GR24, a synthetic analog of strigolactones, stimulates the mitosis and growth of the arbuscular mycorrhizal fungus *Gigaspora rosea* by boosting its energy metabolism, *Plant Physiol.*, **148**: 402-413.
- El-Nakhlawy, F. S.** (2009) *Experimental Design and Analysis in Scientific Research*. Scientific Pub. Center, KAU, Saudi Arabia, (Under Publication) In Arabic.
- Guisso, T., Ba, A.M., Guinko, S., Duponnois, R. and Plenchette, C.** (1999) Rock phosphate and vesicular-arbuscular mycorrhiza effects on growth and mineral nutrition of *Zizyphus mauritiana* Lam. in an alkaline soil, *Ann. Sci. For.*, **55**: 925-931.
- Guisso, T., Ba, A. M., Ouadba, J.M., Guinko, S. and Duponnois, R.** (1998) Responses of *Parkia biglobosa* (Jacq.) Benth, *Tamarindus indica* L. and *Zizyphus mauritiana* Lam. To arbuscular mycorrhizal fungi in a phosphorus-deficient sandy soil, *Biol Fertil Soils*, **28**: 194-198.
- Gupta, N.K. and Mehta, A.K.** (2000) Genetic variability and component characters for fruit yield in ber (*Zizyphus mauritiana* L.), *Advanced Plant Sci.*, **13**: 75-78.
- Hoagland, D.R. and Arnon, D.I.** (1950) The water-culture method for growing plants without soil, *Cal. Agri. Expt. Sta. Circ.*, **347**:1-32.
- Jones, M.D. and Hutchinson, T.C.** (1988) Nickel toxicity in mycorrhizal birch seedlings infected with *Lactarius rufus* or *Scleroderm flavidum*. II- Uptake of nickel, calcium, maganesium, phosphorus and iron, *New Phytol.*, **108**: 461-468.
- Kale, V.S. and Dod, V.N.** (2000) Effect of plant growth regulators on fruit characters and quality of ber (*Zizyphus mauritiana* L.), *Crop Research Hisar.*, **20**: 327-333.
- Khudairi, A. K.** (1969) Mycorrhizae in desert soils, *Bioscience*, **19**: 598-599.
- Likar, M., Bukovnik, U., Kreft, I., Chrungoo, N.K. and Regvar, M.** (2008) Mycorrhizal status and diversity of fungal endophytes in roots of common buckwheat (*Fagopyrum esculentum*) and tartary buckwheat (*F. tataricum*), *Mycorrhiza*, **18**: 309-315.
- Mathur, N. and Vyas, A.** (1995) *In vitro*, production of *Glomus deserticola* in association with *Zizyphus mauritiana*, *Plant Cell Reports*, **14**: 735-737.
- Mathur, N. and Vyas, A.** (1999) Improved biomass production, nutrient uptake and establishment of *in vitro* raised *Zizyphus mauritiana* by VA mycorrhiza, *Journal of Plant Physiology*, **155**: 129-132.
- Nawwar, M.A., Ishak, M.S. and Michael, H.N.** (1984) Flavonoids of *Zizyphus spina-christi*, *Phytochem*, **23**: 2110-2111.
- Okurowska, P.** (2008) Effects of mycorrhizal colonization and fertilization on growth and photosynthesis of sweet basil under salt stress, *J. Plant Nutrition*, **31**: 497-513.
- Olsen, J.K., Scheafer, J.T., Edwards, D.G., Hunter, M.N., Galea, V.J. and Muller, L.M.** (1999) Effects of a network of mycorrhizae on (*Capsicum annuum* L.) grown in the field with five rates of applied phosphorus, *Aust. J. Agric. Res.*, **50**: 239-252.
- Phillips, J.M. and Hayman, D.S.** (1970) Improved procedures for clearing roots and staining parasitic vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection, *Trans. Br. Mycol. Soc.*, **55**: 158-160.

- Porra, R.J., Thompson, W.A. and Kriedemann, P.E.** (1989) Determination of accurate extinction coefficients and simultaneous equations for assaying chlorophylls a and b extracted with four different solvents: Verification of the concentration of chlorophyll standards by atomic absorption spectroscopy, *Biochim. Biophys. Acta.*, **975**: 384-394.
- Said, A.E.** (1986) Propagation of "Cidir" (*Zizyphus spina-christi* L) wild. I. seed germination, *J. Coll. Agri.*, **8**: 389-397.
- SAS Institute Inc.** (2005) *SAS/STAT User's Guide*, SAS Institute Inc, Cary, NC.
- Smith, S.E. and Read, D.J.** (1997) *Mycorrhizal Symbiosis*, Academic Press, London.
- Trouvelot, A., Kough, J.L. and Gianinazzi-Pearson, V.** (1986) "Mesure du taux de mycorrhization d'un systeme racinaire recherché de methods d'estimation ayant une signification fonctionnelle, In: Gianinazzi-Pearson, V. and Gianinazzi, S. (eds). *Physiological and Genetical Aspects of mycorrhiza*". INRA Publications, Paris, pp: 217-221.
- Wang, C.X., Li, X.L., Zhou, J.C., Wang, G.Q. and Dong, Y.Y.** (2008) Effects of arbuscular mycorrhizal fungi on growth and yield of cucumber plants, *Communication in Soil Science and Plant Analysis*, **39**: 499-509.
- Wang, F.Y. and Shi, Z.Y.** (2008) Biodiversity of arbuscular mycorrhizal fungi in China: a Review, *Advances in Environmental Biology*, **2**: 31-39.
- Weinges, K. and Schick, H.** (1995) Dodeca acetyl prodelphinidin B3 from the dried leaves of *Zizyphus spina-christi*, *Phytochemistry*, **38**: 505-507.
- Zoghet, M. and Alsheikh, A.** (1999) *Wild Plants in the Region of Riyadh*, King Saud Univ., Academic Publishing and Press, 234p.

## استجابة نمو نوعين من نبات السدر لفطريات الجذور التكافلية الداخلية

عبد العزيز القرعاوي، و ثبيت الشهراني

قسم الإنتاج النباتي - كلية علوم الأغذية والزراعة - جامعة الملك سعود -  
الرياض - المملكة العربية السعودية

المستخلص. تناول هذا البحث دراسة استجابة نمو والمحتوى الصبغي لنوعين من نبات السدر في المملكة العربية السعودية لتأثير فطريات الجذور التكافلية الداخلية في غرف النمو لمدة ١٢ شهرا. وتم التوصل إلى أن إصابة نباتات السدر بنوعية بفطريات الجذور التكافلية الداخلية إلى زيادة معنوية في كل من الوزن الجاف للسيقان والجذور، بالمقارنة بنظائرها من النباتات غير المصابة لهذه الفطريات. وكانت الزيادة في صفات النمو لهذه النباتات مرتبطة بدرجة كبيرة بدرجة إصابتها بهذه الفطريات. كذلك أوضحت الدراسة أن كلاً من حجم، ومساحة، وطول، وقم الجذور زادت بدرجة معنوية كبيرة في نباتات السدر المتكافل مع فطريات الجذور التكافلية الداخلية، وبصفة خاصة في نوع *Zizyphus spina-christi* بالمقارنة بالنباتات غير المصابة بهذه الفطريات. على الجانب الآخر، لم تظهر النتائج أي فروق معنوية في مساحة سطح، وحجم الجذور بين النباتات المصابة وغير المصابة بهذه الفطريات في نوع *Z. nummularia*. وزاد المحتوى الصبغي (الكلوروفيل أ، ب) في أوراق نباتات السدر بنوعيه معنويا، نتيجة الإصابة بفطريات الجذور التكافلية، مقارنة بالنباتات غير المصابة بهذه الفطريات. وكانت هذه الزيادات مرتبطة بدرجة كبيرة بدرجة

إصابة النباتات بالفطريات. تؤكد النتائج التي تم التوصل إليها أن فطريات الجذور التكافلية يمكن استخدامها كسماد حيوي لزيادة نمو وإنتاجية نباتات السدر بنوعيه، وبصفة خاصة في الترب الفقيرة والتي تتعرض لظروف بيئية قاسية.