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Effects of Controlled Mycorrhization on Production of *Jacaranda mimosifolia* D. Don

Zaouchi Yousr*, Ben Bahri Nada, Ben Jeddi Faysal, Rezgui Salah, Bettaieb Taoufik

Institut National Agronomique de Tunisie (INAT), 1082 Tunis - Mahrajène, Tunisie.

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*Corresponding Author

Zaouchi Yousr

E-mail: yosr_zaouchi_koubaji@live.fr

Phone: (+216) 71 28 71 10,

Fax: (+216) 71 79 93 91

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ABSTRACT

Growth and mineral absorption of ornamental woody plant such as *Jacaranda mimosifolia* D. Don., in gnotoxenic conditions out of a mycorrhization by a commercial inoculum containing *Glomus irregulare* were studied.

Used *Jacaranda* plants are one- year old, they were first grown, in 10/12cm caliber pots then in 16/18cm caliber pots for 6 months in a sterile substrate consisting of 2/3 commercial peat and 1/3 sand. Four treatments, achieved three times, were processed. Apart from the control, two other treatments consisted of the addition of commercial inoculum containing *Glomus irregulare* to the culture substrate, at a rate of 62.5 mg / plant for the first and 100 mg / plant for the second. These quantities respectively correspond to 100 propagules / plant and 160 propagules / plant. The fourth treatment is illustrated by the incorporation of 4g/plant of OSMOCOT EXACT standard-Scotts fertilizer; 15 + 9 + 12 (+2.5), into the substrate. Mycorrhization rate of inoculated plants by 100mg/plant dose reached 43.21% while it only reached 21.48% for those that received 62.5mg/plant. Colonization remains at the beginning of installation presenting essentially mycorrhizal hyphae structures. Mycorrhization significantly improves nitrogen, phosphorus and potassium nutrition of *Jacaranda*. This result in a stimulation of plant growth Level of mycorrhization by 21.48%, and achieve gains of aerial dry biomass of about 45.5% and root volume of about 46.29%. When the level of mycorrhization is equal to 43.21%, these gains correspond to, respectively, 59.1% and 67.28%. Fertilization provides for gains of 29.58% in aerial dry biomass and 9.69% in plants height. It has no effect on roots volume.

1. INTRODUCTION

Benefits offered by mycorrhizae to host plants, have been widely described, especially for the water uptake (Nouaim and Chaussod, 1996; Marulanda et al., 2006; Aroca et al., 2007) and mineral nutrition (Clark and Zeto, 2000; Graham, 2000; Mäder et al., 2000; Hodge et al., 2001; Aliasgharzad et al., 2009). The vesicular-arbuscular mycorrhizae enable the plant to access a larger volume of soil and a greater surface absorption through fungal hyphae (Bucher, 2007; Smith and Read, 2008).

Since *Glomus* is the most ubiquitous vesicular-arbuscular mycorrhizal fungi, it is one of the most studied genus. There has been a big interest in mycorrhization by *Glomus* for the growth of woody plants, such as olive tree (Citernes et al., 1998), Kiwi (Schubert et al., 1992), date palm (Oihabi, 1991), argan tree (Bousselmame et al., 2002) and apple tree (Morin et al., 1994), as well as for ornamental woody plants such as *Junipercs sabina* 'Blue Danube', *Cornus stolonifra* var *coloradensis* and *Prunus x cisten* (Trépanier, 1998). The inoculations are performed *in vitro* axenic conditions or in gnotoxenic conditions (nursery and on a sterile substrate) (Bousselmame et al., 2002).

Jacaranda mimosifolia D. Don is an ornamental woody plant originating from north-western Argentina and southern Brazil (Miyajima et al., 2005). It is used in Tunisia as ornamental plants along avenues and parks. Its mycorrhization may result in better nutrition and growth, as well as smoother adaptation to climatic and urban conditions of Tunisia.

The aim of this study is to evaluate the potential of commercial mycorrhizal *inoculum* to foster the growth and production of *Jacaranda mimosifolia* D. Don plants in nurseries.

2. MATERIALS AND METHODS

2.1. Description of the used *inoculum*

The endomycorrhizal *inoculum* used is a commercial product. It belongs to the brand MYKE PRO which is produced by the company Premier Tech Ltée de Rivière-du-Loup. This product contains an active ingredient; *Glomus irregulare* which is an arbuscular mycorrhizal fungi, with a proportion of 1600 propagules / g, a density of 500 g / l and a granulometry of 0.5 mm. The *inoculum* bag was stored at 4 ° C until use.

2.2. Treatments applied

Four treatments were applied (Table 1). Apart from non fertilized control substrate without inoculum (T), a treatment is conceived through a substrate mixed with diffusion NPK fertilizer containing magnesium and trace elements 15 + 9 + 12 (+2.5): Osmocote EXACT standard-Scotts (F). The detailed composition of this fertilizer is displayed in Table 2. The used fertilizer dose is equal to 4g / plant. The proportions of nitrogen

(N), phosphorus (P₂O₅) and potassium (K₂O) sources in accordance with the fertilizer dose are presented in Table 3. The other two treatments comprise two doses of *inoculum*; 62.5 mg *inoculum* / plant (100 propagules / seed) and 100 mg of *inoculum* / plant (160 propagules / plant) (M1 and M2). Each treatment was performed three times, that is each experimental unit included three pots containing only one plant to be assessed. Since all the assessments were carried within a greenhouse, it was assumed that all experimental units were homogeneous. An experimental design completely randomized was used according to the following model:

$$y_{ij(k)} = \mu + I_i + F_j + \varepsilon_{ij(k)}$$

where $y_{ij(k)}$ = is the value of the response measured for the i th *inoculum* dose (I), j th fertilizer dose (F) in the k th pot

μ : overall mean response

I_i : Effect of the i th *inoculum* dose (I)

F_j : effect of the, j th fertilizer dose (F)

$\varepsilon_{ij(k)}$: experimental error.

2.3. Plant Material and Cultivation

The study is carried in an experimental greenhouse, under homogeneous conditions where the temperature was maintained constant at 25 °C. The greenhouse is located at the horticultural science laboratory of the "Institut National Agronomique de Tunisie" (INAT). The experiment started in May 2010. The culture duration is 6 months. One- year old and 40cm high, young *Jacaranda mimosifolia* D. Don plants bare rooted are planted in pots of 10/12cm caliber (Figure 1). To ensure that the treatments are not pre-mycorrhized, roots are collected randomly at various levels of the underground part of each plant. Microscopic observations of colored root fragments revealed that these plants are not mycorrhized since no mycorrhizal structure was detected. Thus, the plants are considered free of any mycorrhizal infection. A slight thinning out of the roots is carried before potting. The growth substrate consists of 2/3 commercial peat and 1/3 sand. Before planting, pots are washed with tap water and then placed in immersion in chlorine bleach (Chlore 12 °) for 48 hours. Peat and sand are disinfected twice at 120 ° C within an autoclave for 15 minutes for two consecutive days in order to eliminate all germs and pathogens that may harm mycorrhizal colonies and avoid introduction of mycorrhizal propagules in non-inoculated cultures (control or fertilized plants).

Jacaranda plants are placed in the greenhouse and are watered to field capacity every two days. After two months of cultures, these plants are transplanted into clod in 16/18 dimension pots (Figure 1). The substrate aimed at repotting also comprises 2/3 peat and 1/3 sand. Pots and culture substrate are disinfected by the same method used in the cultivation.

2.4. Observed parameters

Jacaranda plant growth is evaluated through measurements of their dry biomass, height (Measurement of longest stem from the neck to the top), leaf area and root volume. Leaf area is measured by a planimeter for bench top. The root volume is assessed according to the method of Musick et al. (1965) consisting of comparing the levels of water before and after immersion of the roots in a given volume. The dry biomasses of root and aerial parts are weighed after drying at 60 °C until reaching a constant weight (Heitholt, 1989). The effects of mycorrhization on major elements nutrition of *Jacaranda* are evaluated by measuring nitrogen, phosphorus and potassium levels in root and aerial parts of the plants. Samples of dry plant material are ground into powder using a grinder. Nitrogen is dosed using the Kjeldahl method (1883). For phosphorus and potassium contents dosing, samples of dried plant powder were calcined in a muffle furnace at a temperature of 450 °C and they were attacked by hydrochloric acid and filtered. Obtained extract is used for the dosage of phosphorus by the monovanadate method through an atomic absorption spectrophotometer (Olsen et al., 1954). For potassium, it was done using flame photometer.

2.5. Evaluation of mycorrhizal colonization

An estimation of root colonization rates is performed not only to determine the levels of mycorrhization of *Jacaranda* plants inoculated with *Glomus irregulare* but also to confirm that there was no endomycorrhizal infection of control or fertilized plants. Root fragments are randomly selected at various levels of underground parts of different plants. Intracellular constituents are eliminated from root tissue by thinning out using KOH (10%) and oxidation of organic matter. Fungal structures are preserved. The roots are then stained with fushine acid (0.05% in lactoglycerol) and stored in lactoglycerol (25% lactic acid, 25% glycerol, and 50% water) to dilute the unfixed colorant and prevent drying. Fushine acid is a colorant which fixes chitin of all fungal structures. According to Tellal et al. (2008), root is considered as endomycorrhized when it presents endomycorrhizal structures (mycelium, vesicule and arbuscule). The rate of mycorrhization of a root by endomycorrhizal fungus is obtained through the method of McGonigle and Fitter (1990). For the quantification of endomycorrhizae, microscopic examination (40 to 200x) of 80 roots one-centimeter-length fragments is performed for each plant. The root fragments were randomly selected and put in parallel by groups of 10 between slide and cover. Three readings per fragment were conducted to determine the type of fungus structure.

3. RESULTS

Jacaranda mycorrhization rate recorded 6 months after *Glomus irregulare* intake is illustrated in Figure 2.

Despite intra treatment variability for M2 dose inoculated plants, they display in average, a higher mycorrhization level than those that received M1 dose. The root infection is more significant when there are larger quantities of *inoculum*. Increasing the *inoculum* dose from 62.5 mg / plant to 100mg/plant improves the *Jacaranda* mycorrhization rate up to 50.29%. Thus, this rate increases from 21.48% to 43.21%. Microscopic observations show small colonies dispersed over mycorrhized roots instead of mycorrhizal fungal structures extending over their entire lengths. Colonization is essentially observed under the shape of hyphae, with very few vesicules and arbuscules (Figure 3).

Mycorrhization of *Jacaranda* at the rate of 43.21% (M2 treatment) improves the plant's growth, especially the aerial biomass, height and root volume ($p = 0.01$) (Table 4). In this case, the gains fulfilled respectively correspond to 59.10%, 24.94% and 67.28%.

The mycorrhization values of dry root biomass and leaf area of fertilized and control plants are not significantly different (Table 4). However, the highest values are observed through a mycorrhization of 43.21% (Table 4). Even the effect is not clear; improvements of root biomass and leaf area of the mycorrhized plants are probably related to the symbiotic association. In fact, according to the results shown in Table 6, these two growth parameters are positively and directly correlated with the *Jacaranda* mycorrhization rate. This mycorrhization increases output by 73.62% of root dry biomass and allow for gaining 56.35% in leaf area compared to control samples. Figure 4 shows the mean dry biomass of *Jacaranda* treatments, assessed after six months of cultivation. Mycorrhized plants, including the M2 treatment (mycorrhization rate 43.21%) have the greatest dry biomass.

Compared with controls, mycorrhization improves nitrogen and phosphorus levy balance sheet in aerial and root parts of *Jacaranda* plants (table 5). A potassium yield improvement of 79.34% is also observed at the root parts of M2 *Jacaranda* treatments (table 5).

For the aerial parts of M1 and M2 treatments, improvements in yields are respectively 55.08% and 57.57% for nitrogen nutrition, and 66.24% and 65.65% for phosphate nutrition. For the root parts of M1 and M2 treatments, improvements in yields are respectively 41.64% and 78.98% for nitrogen nutrition, and 40% and 70.5% for phosphate nutrition.

Fertilization with 4g / plant of Osmocote EXACT standard-Scotts (treatment F) slightly accelerates the growth of *Jacaranda* compared to controls (Table 4). This improvement is reflected by increases in yields of aerial dry biomass and heights of fertilized plants respectively equal to 29.58% and 9.69%. Fertilization with 4g/plant shows nutritional yield close to that of controls (table 5). Only an improvement of 48.38% of root nitrogen balance is observed.

4. DISCUSSION

In nursery conditions, inoculation of *Jacaranda* with two doses of *Glomus irregulare* shows, after 6 months, average levels of mycorrhization. Increasing the *inoculum* dose provides a greater root colonization. In fact, for equivalent culture substrate quantities, two treatments of *inoculum* dose were tested: 62.5mg *inoculum* / plant and 100mg *inoculum* / plant, which correspond to 100 propagules / seedlings and 160 propagules / plant. Plants grown in pots containing the highest number of propagules are more mycorrhized because their roots are more likely to be displayed to an endomycorrhizal propagules and be infected by it.

According to Boussemmane et al. (2002), the kinetics of mycorrhization is characterized by three phases: the installation of a mycorrhizal fungus, the rapid increase of the infection and finally the stabilization of the latter, which is represented by a tray (Moss et al., 1981). Based on the observed mycorrhizal structures which are essentially hyphae, root colonization of *Jacaranda* focuses on the two first phases. The low rate of the exchange and reserve structures reflects a beginning of installation of a symbiotic association between the host plant and *Glomus irregulare*. The large mycorrhization variability rates of M2 treatments dismiss the fact that the infection may have occurred in the stabilization phase. Mycorrhization rate and duration of symbiotic association establishment depend on the host, the infectious potential of mycorrhizal fungi and the substrate cultivation used (Plenchette and Fardeau, 1988). Boussemmane et al. (2002) obtained mycorrhized argan plants using two strains of *Glomus* genus, at a rate of 70% after 4 months of their inoculation. The argan tree cultivation was conducted on a similar substrate used for *Jacaranda*. This delay in the infection of the latter by *Glomus irregulare* can be attributed to the late inoculation of one-year-old young plants while, for the argan tree Boussemmane et al. (2002) inoculated seeds. The mycorrhizal potential of an *inoculum* is greater when it is brought at an early stage, especially in seedlings (Echairi et al., 2008).

Mycorrhization by *Glomus irregulare* of young *Jacaranda* plants has improved nutrition especially that of nitrogen and phosphorus, but also that of potassium with less apparent effect. This improvement is much greater than that obtained by fertilization. These results corroborate those of Leye et al. (2009), where mycorrhization with *Glomus irregulare*, *Glomus fasciculatum*, *Glomus aggregatum* and *Glomus mosseae* on different provenances of *Jatropha curcas* L. showed, after four months of cultivation in greenhouses, a significant improvement in the phosphorus, nitrogen and potassium plants concentrations. Dione et al. (2004) observed an improvement in the nitrogen absorption of *Allocasuarina verticillata* (Lam.) L. Johnson and *Casuarina equisetifolia* (L.) after a mycorrhization with *Glomus fasciculatum* and *Glomus mosseae*. These same authors found that mycorrhization with *Glomus aggregatum* significantly improves phosphorus and potassium absorption of *Allocasuarina verticillata* and had no effect on that of *Casuarina equisetifolia*.

Improved potassium nutrition has also been observed in *Allocasuarina verticillata* after its mycorrhization with *Glomus fasciculatum*. Boussemmane et al. (2002), observed a positive effect on phosphorus and potassium nutritions of mycorrhized argan tree by two strains of *Glomus*. No significant effect was found concerning the nitrogen nutrition.

Jacaranda greatly benefits from the action of *Glomus irregulare*, including its ability to access and take nitrogen and phosphorus from the substrate, which promotes the growth of seedlings. mycorrhization increases the absorption surface of the host plant by fungal hyphae that prolong somehow its root system, allowing access to a greater volume of mineral elements, especially those that are less mobile (N, P, K) (Bolan, 1991).

Mycorrhization of young *Jacaranda* plants by *Glomus irregulare* stimulated their mineral nutrition. This phenomenon resulted in a higher production of dry biomass at the aerial part level and a stimulation of the establishment of a highly ramified root system involving much larger root volumes than those of the control samples. The improvement of the growth is clearer for the more colonized plants, i.e. those whose mycorrhization rate is 43.21%. These have the highest stems. However, the results show that the "stem height" parameter is not correlated with the rate of mycorrhization. Several studies have focused on the stimulatory effects of mycorrhizae on biomass production of their host plants, such as *Calliandra calothyrsus* (Ingleby et al., 2001). Mycorrhization of onion variety "Sivan" by *Glomus aggregatum*, *Glomus fasciculatum* and *Glomus mosseae* allows a significant increase in the average weight of bulbs compared to non-inoculated or fertilized plants (Sow et al., 2008). Laminou Manzo et al. (2009) found a significantly positive effect on the total biomass production of dunes fixing species mycorrhized by *Glomus irregulare*: *Acacia raddiana* Savi; *Acacia nilotica* (L.) Willd Ex Del. var. *adansonii*; *Acacia senegal* (L.) Willd; *Prosopis chilensis* Stunz and *Bauhinia rufescens* Lam. According to Strullu and Plenchette (1991), the extramatriciels hyphae of arbuscular endomycorrhizal fungus are responsible for this positive effect of mycorrhization on growth and nutrition of host plants, since they allow exploring of a greater volume of substrate.

Based on the results, it appears that the leaf area of young *Jacaranda* plants is not influenced by *Glomus irregulare* intake. However, an increase of this parameter is observed for mycorrhized plants at a rate of 43.21%. The results also indicate that it is positively correlated with the rate of mycorrhization ($p = 0.05$). This effect could be highlighted if the colonization would have reached a more advanced stage and if the exchange structures between the symbiotic and the woody plant had been installed. A positive effect was observed by Schubert et al. (1992) on the leaf surface of mycorrhized kiwi vitroplants (*Actinidia deliciosa*) by a strain of *Glomus*.

5. CONCLUSION

Mycorrhization by *Glomus irregulare* significantly stimulates nutrition and growth of young *Jacaranda* plants cultivated under nursery conditions. The results of this experiment can confirm the advantages of mycorrhizal inoculation for the nursery culture of *Jacaranda* since the growth of inoculated plants is faster than control plants growth. In comparison with yields of fertilized culture, mycorrhization made similar gains, even greater. This promotes the use of

mycorrhizae as substitutes for pollutant chemical products. These results are also encouraging to conduct further studies aimed at selecting indigenous strains of mycorrhizae, which are more efficient and better adapted to soil environmental conditions. However, the earlier addition (at seeding) of commercial *inoculum* could have allowed to getting more mycorrhized plants in order to obtain a faster growth.

Table 1: Treatments applied

Treatment	T	F	Mycorrhized 1 (M1)	Mycorrhized 2 (M2)
Inoculum dose (mg)	0	0	62.5	100
Fertilizer dose (g)	0	4	0	0
Repetitions number	3	3	3	3

Table 2: Composition of fertilizer Osmocote EXACT standard-Scotts

Element	Concentration (%)
Nitrogen (N)	15
Phosphoric anhydride (P ₂ O ₅)	9 soluble in neutral ammonium citrate and in water; 6.8 soluble in water
potassium oxide (K ₂ O)	12 soluble in water
magnesium oxide (MgO)	2.5 and 1.3 soluble in water
bore (B)	0.02 soluble in water
copper (Cu)	0.068 and 0.051 soluble in water
total iron (Fe)	0.45 and 0,08% chelated by EDTA
manganese (Mn)	0.06 et 0.03% soluble in water
molybdenum (Mo)	0.025 soluble in water
zinc (Zn)	0.02 and 0.013 soluble in water

Table 3: Proportions in nitrogen (N), phosphorus (P₂O₅) and potassium (K₂O) sources corresponding to the dose of fertilizer applied

Dose of fertilizer Osmocote Exact (g/ plant)	4
Quantity brought of Nitrogen source (N :mg/plant)	600
Quantity brought of phosphorus source (P ₂ O ₅ :mg/plant)	360
Quantity brought of potassium source (K ₂ O:mg/plant)	480



Figure 1: Young *Jacaranda* plants cultivated in pots, under greenhouse in a sterile substrate. A: plants cultivated in 10/12cm caliber pots; B: Plant grown in a 16/18 cm caliber pot.

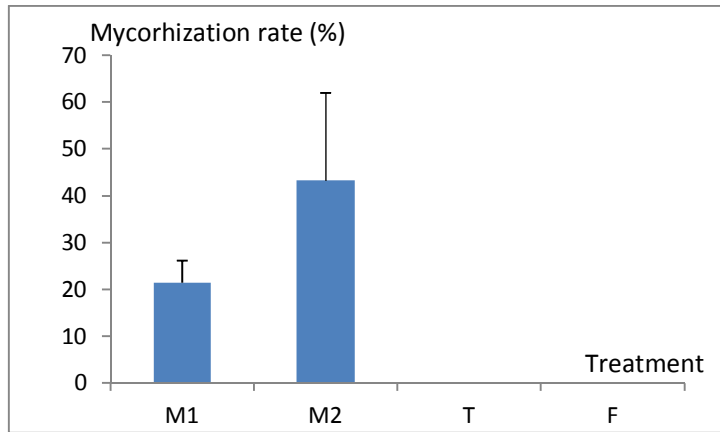


Figure 2: Mycorrhization rate of *Jacaranda* plants by *Glomus irregulare*.

M1 = 62.5 mg *inoculum* /plant

M2= 100 mg *inoculum* /plant

T : control

F : 4 g Osmocote/plant

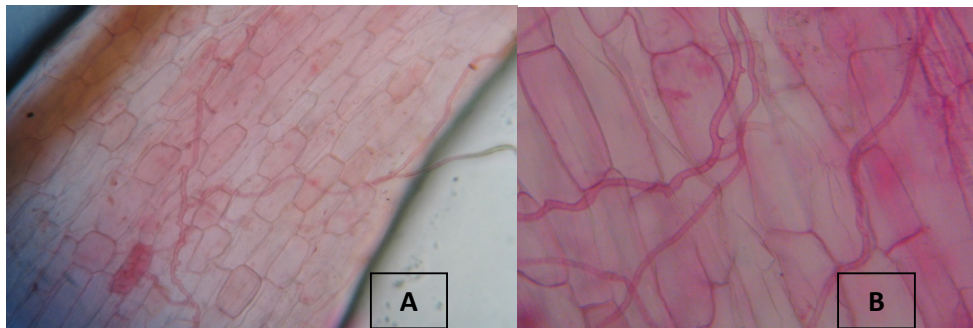


Figure 3: Observed structures on a root fragment of *Jacaranda mimosifolia* D. Don, 6 months after inoculation by a commercial *inoculum* containing *Glomus irregulare*.

A: Hyphae forming arbuscule (100 times larger picture); B: hyphae (400 times larger picture).

Table 4: Effects of inoculation with *Glomus irregulare* on aerial and root dry biomass, height, foliar surface and root volume of *Jacaranda* plants

treatment	Aerial dry biomass (g)	Root dry biomass (g)	Stem height (cm)	foliar surface (cm ²)	root volume (ml)
M1	7.01 b	2.21 b	49.54 b	233.04 b	22.34 b
M2	9.34 a	6.14 a	66.17 a	355.22 a	36.67 a
F	4.95 bc	2.13 b	55.00 ab	280.64 b	14 c
T	3.82 c	1.62 b	49.67 b	155.06 c	12 c
F trait	**	ns	**	ns	**
R²	0.93	0.58	0.94	0.50	0.98
Coefficient of variation	6.85	14.92	5.79	25.54	6.24

** : Significant difference between treatments ($p= 0.01$)

ns : No significant difference between treatments

(Values followed by the same letter are not significantly different)

Table 5: Effect of inoculation by *Glomus irregulare* on nitrogen, phosphorus and potassium balance sheets taking of the aerial and root parts of *Jacaranda* plants

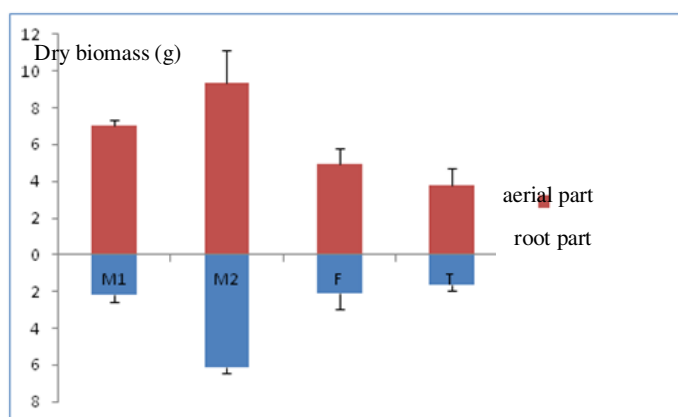
Treatment	Aerial part			Root part		
	N (10 ⁻² g)	P (10 ⁻² g)	K (10 ⁻² g)	N (10 ⁻² g)	P (10 ⁻² g)	K (10 ⁻² g)
M1	8,37 a	4,65 a	18,23 ba	2,45 b	1,20 b	1,29 b
M2	8,86 a	4,57 a	38,17 a	6,80 a	2,44 a	5,42 a
F	6,14 ba	2,10 b	10,20 ba	2,77 b	1,03 bc	1,62 b
T	3,76 b	1,57 b	4,91 b	1,43 c	0,72 c	1,12 b
F trait	*	**	ns	**	**	**
R²	0,82	0,95	0,56	0,98	0,96	0,99
coefficient of variation	20,28	14,99	88,28	12,67	15,63	13,28

** : Significant difference between treatments ($p= 0.01$)

* : Significant difference between treatments ($p= 0.05$)

ns : No significant difference between treatments

(Values followed by the same letter are not significantly different)

**Figure 4: Mean dry biomass of *Jacaranda* treatments evaluated after six months of culture.**

M1 = 62.5 mg *inoculum* /plant

M2= 100 mg *inoculum* /plant

F : 4 g Osmocote/plant

T : control

Table 6: Correlation between the mycorrhization rate and growth parameters of *jacaranda*, after 6 months from the inoculation with *Glomus irregulare* (Pearson correlation coefficient, N= 12)

	Aerial biomass	dry Root biomass	dry root volume	Stem height	Surface foliaire
Mycorrhization rate	0.96 **	0.83 **	0.98 **	0.54 ns	0.62 *

** The correlation is significant at the level of 0.01

* The correlation is significant at the level of 0.05

ns No correlation

REFERENCES

- Aliasghar zad N, Bolandnazar SA, Neyshabouri MR and Chaparzadeh N, (2009). Impact of soil sterilization and irrigation intervals on P and K acquisition by mycorrhizal onion (*Allium cepa* L.). *Biologia* 64: 512-515.
- Aroca R, Porcel R and Ruíz-Lozano JM, (2007). How does arbuscular mycorrhizal symbiosis regulate root hydraulic properties and plasma membrane aquaporins in *Phaseolus vulgaris* under drought, cold or salinity stresses?. *New Phytologist* 173: 808–816.
- Bolan NS, (1991). A critical review on the role of mycorrhizal fungi in the uptake of phosphorus by plant. *Plant and soil* 134 : 189-207.
- Bousselmame F, Kenny L and Achouri M, (2002). Effet des mycorrhizes à vésicules et arbuscules sur la croissance et la nutrition de l'arganier (*Argania spinosa* L.). *Revue Marocaine des Sciences Agronomiques et Vétérinaires. Actes Institut Agronomique et Vétérinaire (Maroc)* 22 (4) : 193-198.
- Bucher M, (2007). Functional biology of plant phosphate uptake at root and mycorrhiza interfaces. *New Phytol.* 173: 11-26.
- Citernes AS, Vitagliano C and Giovannetti M, (1998). Plant growth root system morphology of *Olea europaea* L. Rooted cuttings as influenced by arbuscular mycorrhizas. *S J Horticult Sci Biotechnol.* 73(5): 647-654
- Clark RB and Zeto SK, (2000). Mineral acquisition by arbuscular mycorrhizal plants. *Journal of Plant Nutrition* 23: 867–902.
- Dione Y, Sy MO, Diop AT, Diallo A and Ba AT, (2004). Réponse d'*Allocasuarina verticillata* (Lam.) L. Johnson et de *Casuarina equisetifolia* (L.) à l'inoculation mycorrhizienne arbusculaire. *J. Fac Sciences.* 3 (1): 20-28.
- Echairi A, Nouaim R and Chaussod R, (2008). Intérêt de la mycorrhization contrôlée pour la production de plants d'arganier (*Argania spinosa*) en conditions de pépinière. *Sécheresse* 19 (4): 277-281.
- Graham JH, (2000). Assessing costs of arbuscular mycorrhizal symbiosis in agroecosystems. In: *Current advances in mycorrhizae research*. Eds. Podila G.K., Douds D.D. Jr.: 127–140.
- Heitholt JJ, (1989). Water use efficiency and dry matter distribution in nitrogen- and water-stressed winter wheat. *Agronomy Journal* 81: 464.
- Hodge A, Campbell CD and Fitter AH, (2001). An arbuscular mycorrhizal fungus accelerates decomposition and acquires nitrogen directly from organic material. *Nature* 413: 297–299.
- Ingleby K, Fahmer A, Wilson J, Newton AC, Manson PA and Smith RI, (2001). Interactions between mycorrhizal colonisation, nodulation and growth of *Calliandra calothyrsus* seedlings supplied with different concentrations of phosphorus solution. *Symbiosis*: 30 (1): 15-28.
- Kjeldahl J, (1883). Neue Methode zur Bestimmung des Stickstoffs in organischen Körpern. *Z. Anal. Chem* 22 : 366-382.
- Laminou Manzo O, Ibrahim D, Campanella B and Paul R, (2009). Effets de l'inoculation mycorrhizienne du substrat sur la croissance et la résistance au stress hydrique de cinq espèces fixatrices de dunes : *Acacia raddiana* Savi ; *Acacia nilotica* (L.) Willd. Ex Del. var. *adansonii* ; *Acacia senegal* (L.) Willd ; *Prosopis chilensis* Stunz. et *Bauhinia rufescens* Lam.. *Geo-Eco-Trop.* 33,n.s. : 115 – 124.
- Leye EHM, Ndiaye M, Ndiaye F, Diallo B, Sarr AS, Diouf M and Diop T, (2009). Effet de la mycorrhization sur la croissance et le développement de *Jatropha curcas* L. *Revue des Energies Renouvelables* 12 (2) : 269 – 278.
- Mäder PA, Vierheilig H, Streitwolf-Engel R, Boller T, Frey B, Christie P and Wiemken A, (2000). Transport of 15N from a soil compartment separated by a polytetrafluoroethylene membrane to plant roots via the hyphae of arbuscular mycorrhizal fungi. *New phytologist* 146: 155-161.
- Marulanda A, Barea JM and Azcón R, (2006). An indigenous drought-tolerant strain of *Glomus intraradices* associated with a native bacterium improves water transport and root development in *Retama sphaerocarpa*. *Microbiol Ecology* 52: 670–678.
- McGonigle TP and Fitter AH, (1990). Ecological specificity of vesicular-arbuscular mycorrhizal associations. *Mycological Research* 94 (1): 120–122.
- Miyajima I, Kato A, Hagiwara JC, Mata D, Facciuto G, Soto S, Escandon A, Mori M and Kobayashi N, (2005). Promotion of immature seed germination in *Jacaranda mimosifolia*. *Hortscience* 40: 1485-1486.
- Morin F, Fortin JA, Hamel C, Granger RL and Smith DL, (1994). Apple rootstock response to vesicular arbuscular mycorrhizal fungi in a high phosphorus soil. *J Amer Soc Hort Sci.* 119(3): 578-583.

- Moss B, Stribley DP and Le Tacon F, (1981). Ecology of mycorrhizae and mycorrhizal fungi. *Advances Microbial Ecology* 5: 134-210.
- Musick GJ, Fairchild ML, Ferguson VL, Zuber MS and Crop J, (1965). A method of measuring root volume in corn (*Zea mays* L.). *Crop Science* 5 : 601-602.
- Nouaïm R and Chaussod R, (1996). Rôle des mycorhizes dans l'alimentation hydrique des plantes, notamment des ligneux en zones arides. *Options Méditerranéennes* 20: 9-26.
- Oihabi A, (1991). *Étude des endomycorhizes à vésicules et arbuscules sur le Bayoud et la nutrition du palmier dattier*. Thèse de doctorat : Univ. Cadi Ayyad (Marrakech).
- Olsen SR, Cole CV, Watanabe FS and Dean LA, (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA Circular*, 939,1-19. Gov. Printing Office Washington D.C
- Plenchette C and Fardeau JC, (1988). Effet du pouvoir fixateur du sol sur le prélèvement de phosphore du sol par les racines et les mycorhizes. *C R Acad Sci Paris* 306: 201-206.
- Schubert A, Bodrino C and Gribaudo I, (1992). Vesicular-arbuscular mycorrhizal inoculation of kiwifruit (*Actinidia deliciosa*) micropropagated plants. *Agronomie* 12: 847-850.
- Sow HA, Diop TA, Ndiaye F, Manga AGB and Diallo A, (2008). Influence de la mycorhization arbusculaire sur la culture intensive de l'oignon (*Allium cepa* L.) au Sénégal. *Journal des Sciences* 8(1): 1-6.
- Smith SS and Read DJ, (2008). *Mycorrhizal Symbiosis*. Academic Press.
- Strullu DG and Plenchette C, (1991). Les mycorhizes en horticulture. *PHM Revue Horticole* 352 : 50-55.
- Tellal M, Qarro M, Arahou M, Abourouh M, Tellal R, Rhazi L and Douira A, (2008). Effet de l'actinomycète *Frankia* sur la croissance et la fixation de l'azote de *Casuarina glauca* et *Casuarina cunninghamiana*. *Science et changements planétaires / Sécheresse* 19 (3) : 211-6.
- Trépanier M, (1998). Effet des champignons endomycorhiziens sur le bouturage et la croissance de plantes ligneuses ornementales. Thèse de doctorat : Faculté des sciences de l'agriculture et de l'alimentation- Département de phytologie - Université de Laval (France).

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