WFL Publisher
Science and Technology

Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.7 (3&4) : 461-463. 2009

www.world-food.net

Effect of vesicular-arbuscular mycorrhiza (VAM) on yield of sorghum cultivars

A. Mehraban [1]*, S. Vazan [2], M. R. Naroui Rad [3] and A. R. Ardakany [2]

*[1] Department of Agronomy, Islamic Azad University, Tehran, Iran. [2] Islamic Azad University, Karaj, Iran. [3] Agriculture and Natural Resources Research Center of Sistan, Iran. *e-mail: Ahmadmh2005@yahoo.com, narouirad@gmail.com*

Received 23 May 2009, accepted 11 October 2009.

Abstract

The fungi of vesicular-arbuscular mycorrhiza (VAM) as a benefit microorganism are used in various purposes, such as mining, agriculture and environmental science. In agriculture, utilization of VAM as benefit manner and biological efficiency for plant growth and nutrition is an important symbiotic with crops. The effects of different mycorrhizal fungi symbiosis with sorghum genotypes were studied in growing season 2006-2007 in Agriculture and Research Institute of Dryland Area, Zabol, Iran. This experiment was based on factorial completely randomize design with two factors in four replications in field condition. The first factor was in three levels including KGS 25, KGS 29 and native. The second factor was mycorrhiza in three levels including without mycorrhiza and various species of *Glomus etanicatum* and *G. mossae*. The results showed that there are significant differences between cultivars of sorghum and using mycorrhiza on plant height, number of seed in spike, biomass, root colonization. Also the results indicated that in order augmentation of plant growth and crop yield it is necessary to choose the most effective fungus species. *G. mosseae* species were best mycorrhiza strains among studied species. VAM colonization improved most characteristics of sorghum in semiarid lands.

Key words: Mycorrhiza, *G. mossae*, *G. etanicatum*, sorghum.

Introduction

In many arid and semiarid regions, water stress has limited crop productivity [15] and drought is considered the single most important biotic stress that limits crop production in these areas [14]. The vesicular-arbuscular mycorrhizal (VAM) fungal symbiosis is widely believed to protect host plants from detrimental effects of drought [3, 17]. The VAM is a mutualistic symbiosis between fungi and the roots of terrestrial plants. The ancient fungi colonize approximately 90% of the Earths land plant species [11]. Also improved P nutrition by VAM fungi during the periods of water deficit has been postulated as a primary mechanism for enhancing host plant drought tolerance [7, 10, 16, 20, 21]. In addition to P nutrition, mycorrhiza symbiosis assists host plants to use N forms that are unavailable to non-mycorrhizal plants, thereby contributing to plant growth and nutrition under drought conditions [20, 21].

AMF inoculation has been found to improve the water relations of many plants. For example mycorrhizal colonization of roots has shown to increase drought tolerance of maize [18, 20], wheat [1, 8], soybean [7, 16], onion [6], lettuce [6, 21] and redclover [10]. VAM symbiosis also improved leaf water potential [17], leaf water potential was higher in stressed soybean with VAM than that in corresponding non-VAM plants. The potential mechanisms include (1) extensive absorption of water by external hyphae [5, 9, 17], 2) stomatal regulation through hormonal signals [12], an indirect effect of improved P nutrition upon water relations [10, 16] and greater osmotic adjustment in mycorrhizal plant [3, 4, 16]. We conducted experiments to test whether VAM effects on physiological drought resistance would be more pronounced under dry land condition. We exposed sorghum to various treatments just prior to exposing them to drought, and it would be useful to know if VAM symbiosis can increase resistance to these combined stresses.

Materials and Methods

Soil and site characteristics: A field site was on sandy loam in texture. Neutral in pH, free from salinity (0.2 dS m^{-1}) and available N 1.94 g kg^{-1} at Regional Research station Zahak - Zabol, situated in the eastern dry zone of Sistan and Bluchestan state, Iran, at 30°54'N latitude, 61°41'E longitude and 483 m above sea level with average rainfall of ten years 9.4 mm. The soil was kept fallow for one year to reduce indigenous mycorrhiza fungi and decompose root fragments of previous crop to eliminate propagates. The experiment was conducted during the growing seasons of 2006-2007.

Treatments: The field experiment was conducted on sorghum (*Sorghum bicolor* L.) cultivars KGS25, KGS29 and native cultivar. Mycorrhizal fungus inoculums, consisting of spore, soil and infected jowar root fragment from a stock culture of *G. etanicatum* and *G. mossae* and without mycorrhiza were provided by the Institute of Nutrition and Resources, Karaj Academy of Agriculture and Forestry Sciences.

Experimental design: This experiment was based on completely randomized design with two factors in four replications in field condition. The first factor was in 3 levels, including KGS25, KGS29 and native cultivar. The second factor was mycorrhiza in 3 levels, including without mycorrhiza and *Glomus etanicatum* and *G. mossae.*

Statistical analysis: The experimental data were statistically analyzed by analysis of variance (ANOVA) with SPSS, and significant differences between treatments and interactions and LSD ($P<0.05$) to compare means.

Results

Analysis of variance showed there are significant differences among most traits (Table 1). Mycorrhiza had effects on these characters but there were no significant differences among cultivars for characters except for grain yield and peduncle length (Table 2). There were significant differences for cultivar and mychorrhiza interaction for peduncle length, panicle number, seed number in spike, seed weight and grain yield. We recognized mycorrhiza had good performance for morphological characters because all treatments had good appearance. The maximum coefficient of variation was got for spike width and minimum was recorded for plant height. From aspect of mycorrhiza effects, *G. mossae* had more effect on grain yield than *G. etanicatum*. This case was because of increased in 1000 seed weight, seed weight and number of seeds in spike, but *G. mossae* had more effects on morphological characters, for example leaf width, leaf length and stem diameter. Highest grain yield was got for KGS29, and this genotype had a good response to mycorrhiza application and yield components such as seed weight, seed number in spike and spike length (Table 3). Effect of interaction between cultivar and mycorrhiza on plant growth characters in sorghum are given in Table 4. KGS29 with *G. mossae* had good interaction on grain yield (2181 kg/ha), KGS25 with *G. mossae* had the highest 1000 seed weight and KGS29 and *G. mossae* had good interaction in number of seeds in spike.

Discussion

Mycorrhizal colonization by *Glomus etanicatum* improved growth water status, nutrient content and yield of sorghum. This field study suggests that VAM inoculation improves drought tolerance of sorghum plants as a secondary consequence of enhanced nutritional status, especially N and P, of the host plant. The response to mycorrhizal colonization increased with increasing intensities of drought stress under field conditions (Table 1). Our data agree with the findings of Kothari *et al.* [13] who reported that mycorrhizal colonization with *Glomus fasciculatum* improved the drought tolerance of field-grown maize plants as a result of enhanced P status under varying intensities of drought stress. Others have suggested that the host plant drought tolerance resulting from AM colonization may be explained by a greater root surface area or densely proliferated root growth or hydraulic differences between root systems [4, 11, 13, 16]. The ability of AM fungi to protect the host plant against progressive drought appears to be related to intrinsic capacity of mycorrhizal fungi to resist drought stress and may not be associated with any specific physiological mechanism affected by the *Glomus* species. Several studies have unequivocally demonstrated that plants colonized by AM fungi are much more efficient in taking up soil P than none VAM plants [2, 10, 12, 19, 20].

Conclusions

Mycorrhiza *G. mossae* was more effective in morphological growth of sorghum in arid land of Sistan than *G. etanicatum* and researchers could use this strain to complete information.

Acknowledgements

The authors are gratefully to Mr. Dayi for providing the AMF inoculums and Mr. Ghafaryi for statistical support. Also authors wish to thank the Zabol Institute Agricultural for providing financial support.

References

[1]Al-Karaki, G. N. 1998. Benefit, cost and water-use efficiency of arbuscular mycorrhizal durum wheat grown under drought stress. Mycorrhiza **8**:41-45.

[2]Asmah, A. E. 1995. Effect of phosphorus source and rate of application on VAM fungal infection and growth of maize (*Zea mays* L). Mycorrhiza **5**:223-228.

[3]Auge R.M., Schekel, K.A. and Wample, R.L. 1986. Osmotic adjustment in leaves of VAM mycorrhizal and non-mycorrhizal rose plants in response to drought stress. Plant Physiol. **82**:765-770.

[4]Auge, R. M., Duan, X., Ebel, R. C. and Stodola, A. J. W. 1994. Nonhydraulic signaling of soil drying in mycorrhizal maize. Planta **193**:74-82.

[5]Auge, R.M. 2003. Water relations, drought and vesicular-arbuscular mycorrhizal symbiosis. Mycorrhiza **11**:30-42.

[6]Azcon, R. and Tobar, R. M. 1998. Activity of nitrate reductase and glutamine synthetase in root and shoot of mycorrhizal *Allium cepa*. Effect of drought stress. Plant Sci. **133**:1-8.

[7]Bethlen Falvay, G. J., Brown, M. S., Ames, R. N. and Thomas, R. E. 1998. Effects of drought on host and endophyte development in mycorrhizal soybeans in relation to water use and phosphate uptake. Plant Physiol. **72**:565-571.

[8]Bryla, D.R. and Duniway, J. M. 1997. Growth, phosphorus uptake, and water relations of safflower and wheat infected with and arbuscular mycorrhizal fungus. New Phytol. **136**:581-590.

[9]Faber, B. A., Zasoske, R. J., Munns, D. and Shackel, N. 1991. A method for measuring hyphal nutrition and water uptake in mycorrhizal plant. Can. J. Bot. **69**:87-94.

[10]Fitter, A. H. 1998. Water relations of red clover (*Trifolium pratense*) as affected by VA mycorrhizal infection and phosphorus supply before and during drought. J. Expt. Bot. **39**:595-603.

[11]Gadkar, V., David-Schwartz, E., Kunik, T. and Kapulnik, Y. 2001. Arbuscular mycorrhizal fungi colonization factors involved in host recognition. Plant Physiol. **127**(14):3-90.

[12]Goicoechea, N., Antolin, M. C. and Sanchez, D. M. 1997. Gas exchange is related to the hormone balance in mycorrhizal or nitrogen-fixing alfalfa subjected to drought. Physiol. Plant. **100**:989-970.

[13]Kothari, S. K., Marschner, H. and George, E. 1990. Effects of AM fungi and rhizosphere organisms root and shoot morphology, growth and water relation in maize. New Phytol. **116**:303-311.

[14]Kramer, P. J. and Boyer, J. S. 1997. Water Relations of Plants and Soils. Academic Press, San Diego, USA.

[15]Maggio, A., Reddy, M. P. and Joly, R. 2004. Leaf gas exchange and soluble accumulation in the halophyte (*Salvadora persicol*) grown at moderate salinity Environ. Exp. Bot. **44**:31-38.

[16]Nelsen, C. E. and Safir, G. R. 1982. Increased drought tolerance of mycorrhizal and onions due to improved phosphorus nutruition. Planta **154**:707-713.

[17]Ruiz-Lozano, J.M. 2003.Arbuscular mycorrhizal symbiosis and alleviation of osmotic stress. New Perspectives for Molecular Studies **163**:417-425.

[18]Subramanian, K. S. and Charest, C. 1995. Influence of arbuscular mycorrhizae on the metabolism of maize under drought stress. Mycorrhiza **5**:273-278.

[19]Subramanian, K. S. and Charest, C. 1999. Acquisition of N by external hyphae of an arbuscular mycorrhizal fungus and its impact on physiological response in maize under drought stressed and well watered conditions. Mycorrhiza **9**:69-75.

[20]Subramanian, K.S., Santhanakrishnan, P. and Balasubramanian, P. 2006. Response of field grown tomato plants to arbuscular mycorrhizal fungal colonization under varying intensities of drought stress. Scientia Horticulturae **107**:245-253.

[21]Tobar, R.M., Azcon, R. and Barea, J. M. 1994. The improvement of plant N acquisition from an ammonium treated, drought stressed soil by the fungal symbiont in arbuscular mycorrhizae. Mycorrhiza **4**:105-108.

Table 1. The analysis variance of treatments and mean square of plant growth characters.

SV	Plant growth characters PH	SD	Tno	Ll	Lw	Spl	Spw	Pl	Pno	SiSp	SW	1000SW	GY
Block	50.77 ns	0.001 ns	0.002 ns	10.481 ns	0.111 ns	2.481 ns	0.011 ns	2.815 ns	0.316 ns	1839937 ns	42.183 ns	7.000*	5053.106 ns
Mycorrhiza (A)	2878.11**	0.308**	0.007 ns	55.593*	0.444ns	626.370**	3.44*	31.593**	0.734*	63334791**	9866.227**	9.373**	3912138.28**
Cultivars (B)	8.44 ns	0.048ns	0.002ns	26.704ns	0.111ns	2.481ns	0.788ns	18.037*	0.250ns	1948980ns	297.955ns	1.333ns	233928.69 **
A × B	79.22ns	0.027ns	0.003ns	8.648ns	0.222ns	2.426ns	0.056ns	13.259*	0.473*	2423328*	777.391*	0.500ns	104467.34*
Error	63.82	0.035	0.004	12.856	0.278	3.231	0.0976	3.565	0.125	740893	232.224	1.292	32751.08
CV%	6.20	12.71	12.36	12.84	15.30	9.37	17.41	17.22	15.08	11.74	12.42	6.66	13.66

SV source of variation, PH plant height (cm), SD stem diameter (cm), Tno tiller number, Ll leaf length (cm), Lw leaf width (cm), Spl spike length (cm), Spw spike width (cm), Pl peduncle length (cm), Pno panicle number, SiSp seed number in spike, SW seed weight (g), 1000SW thousand seed weight (g), GY grain yield (g), ns non-significant, ** significant difference at 1%, * significant difference at 5%.

Table 2. Effect of mycorrhiza treatment (±SE) in levels of sourghum cultivars on plant growth characters of sorghum.

Mycorrhiza	Plant growth characters PH	SD	Tno	Ll	Lw	Spl	Spw	Pl	Pno	SiSp	SW	1000SW	GY
Control	49.2±1.007b	1.27±0.284 b	1.10±0.310 a	29.33±236 a	3.22± 0.505a	9.55±0.559 b	3.78±0.221 c	9.67±0.112 b	2.01±0.221 b	5071.67±0.385 c	90.63±10.929c	15.56±1.486 b	649.85±5.434c
G.etanicatum	6.1±0.897a	1.61±0.469a	1.20±0.272a	27.22±0.192 b	3.67± 0.722a	24.22±0.584 a	5.00±0.235 a	13.11±0.130a	2.50±0.359 a	6670.00±0.342 b	119.84±1.608 b	16.89±1.432 ab	1356.00±6.877 b
G. mossae	1.1±0.869a	1.56±0.484 a	1.20±0.221a	27.29±0.221b	3.44±0.504 a	23.78±0.699 a	4.22±0.241b	10.11±0.165 b	2.51±0.186 a	10252.11±0.398 a	156.70±11.825a	17.56±1.616a	1967.32±8.964 a

PH plant height (cm), SD stem diameter (cm), Tno tiller number, Ll leaf length (cm), Lw leaf width (cm), Spl spike length (cm), Spw spike width (cm), Pl peduncle length (cm), Pno panicle number, SiSp seed number in spike, SW seed weight (g), 1000SW thousand seed weight (g), GY grain yield (g).

Table 3. Effect of sorghum cultivars (±SE) in levels of mycorrhiza treatment on plant growth characters.

Cultivar	Plant growth charters PH	SD	Tno	Ll	Lw	Spl	Spw	Pl	Pno	SiSp	SW	1000SW	GY
Native	129.2±1.503a	1.40±0.919a	1.10±0.280a	31.56±0.221a	3.33±0.642a	19.00±0.748a	4.44±0.236a	9.33±0.160a	2.24±0.289a	7021.00±0.430a	116.39±17.092a	16.44±2.013a	1142.19±10.817b
KGS25	127.7±1.143a	1.54±0.901a	1.40±0.236a	25.670.236b	3.44±0.467a	18.78±0.641a	4.56±0.241a	11.89±0.154b	2.24±0.236a	7106.44±0.413a	122.91±16.443a	17.11±1.981a	1382.38±7.214ab
KGS29	129.4±1.437a	1.49±0.901a	1.00±0.369a	26.780.192b	3.56±0.639a	19.78±0.550a	4.00±0.242b	11.67±0.167b	2.53±0.316a	7866.33±0.385a	127.87±16.782a	16.44±2.085a	1448.58±9.053a

PH plant height (cm), SD stem diameter (cm), Tno tiller number, Ll leaf length (cm), Lw leaf width (cm), Spl spike length (cm), Spw spike width (cm), Pl peduncle length (cm), Pno panicle number, SiSp seed number in spike, SW seed weight (g), 1000SW thousand seed weight (g), GY grain yield (g).

Table 4. Effect of interaction between cultivars and mycorrhiza (±SE) on plant growth characters in sorghum.

	Mycorrhiza Control Native	KGS25	KGS29	*G. etanicatum* Native	KGS25	KGS29	*G. mossae* Native	KGS25	KGS29
PH	154±2.141c	141±1.328abc	152±1.582bc	116±0.620a	117±1.652ab	115±0.833a	117±0.075abc	124±1.879a	121±0.783ab
SD	1.67±0.000c	1.37±0.816abc	1.27±0.760bc	1.63±0.439a	1.57±0.981a	1.63±0.439a	1.40±0.439abc	1.70±0.759a	1.57±1.00ab
Tno	1.00±0.439ab	2.00±0.577ab	1.00±0.439ab	1.00±439ab	1.00±0.00ab	1.00±0.439ab	1.00±0.620ab	1.00±0.439ab	1.00±0.00ab
Ll	34.33±0.439a	26.33±0.00b	27.33±0.439b	29.33±0.439ab	25.00±0.00b	27.33±0.439b	31.00±0.00ab	25.67±0.439b	25.67±0.00b
Lw	3.00±0.981a	3.33±1.308a	3.33±1.035a	3.33±0.620a	3.67±0.439a	4.00±0.00a	3.67±0.620a	3.33±0.916a	3.33±0.833a
Spl	9.00±1.035b	9.33±1.035b	10.33±0.362b	24.00±1.620a	24.67±0.939a	24.001.355a	22.33±0.620a	25.00±1.160a	25.00±0.877a
Spw	4.00±0.00d	4.00±0.439d	3.330.439e	5.00±0.438ab	4.33±0.439a	4.67±0.438bc	4.33±0.439cd	4.330.001cd	4.00±0.439d
Pl	8.000.139d	10.33±0.138b	10.67±0.258b	9.33±0.138b	14.33±0.310a	15.67±0.183a	10.67±0.196b	11.00±0.138b	8.67±0.342b
Pno	2.00±0.463bc	2.73±0.462a	2.77±0.310a	1.97±0.310bc	1.63±0.310c	2.43±0.240ab	2.77±0.392a	2.37±0.719ab	2.40±0.240ab
SiSp	5102.67±0.833ef	5492.33±0.577ef	4620.0±0.577f	5666.0±0.438ef	6577.67±0.577de	7766.67±0.816cd	10294.33±0.577ab	9249.33±0.713bc	11212.67±0.714a
SW	92.25±17.873ef	104.84±19.579de	74.4±11.923f	107.63±10.472de	117.87±16.305cd	134.03±27.862bc	149.30±21.725b	146.63±0.557b	174.17±11.009a
1000SW	15±1.919c	16±2.276bc	15±2.311bc	17±1.264abc	17±1.92abc	16±3.709abc	170.3.001ab	18±1.431a	17±2.009abc
GY	587.26±12.539e	769.02±14.398de	593.25±20.359e	988.26±4.015d	1509.05±9.541c	1570.68±0.385bc	1851.05±7.544b	1869.08±12.657b	2181.81±5.763a

PH plant height (cm), SD stem diameter (cm), Tno tiller number, Ll leaf length (cm), Lw leaf width (cm), Spl spike length (cm), Spw spike width (cm), Pl peduncle length (cm), Pno panicle number, SiSp seed number in spike, SW seed weight (g), 1000SW thousand seed weight (g), GY grain yield (g).