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Full Length Research Paper

Solanum cultivar responses to arbuscular mycorrhizal fungi: growth and mineral status

Tahir Abdoulaye DIOP[1,2*], Tatiana KRASOVA-WADE[1,2], Alioune DIALLO[1,2], Meïssa DIOUF[3], Mamadou GUEYE[2]

[1]Département de Biologie Végétale, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, Dakar, BP 5005, Sénégal.
[2]Laboratoire de Microbiologie des Sols, Centre de Recherches ISRA/IRD, BP 1386, Dakar Sénégal.
[3]Institut Sénégalais de Recherches Agricoles/CDH, BP 3120 – Dakar, Sénégal.

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A greenhouse experiment was carried out in a sandy soil with a low available phosphorus to evaluate responsiveness of four *Solanum aethiopicum* cultivars to indigenous arbuscular mycorrhizal fungi. Results showed clear interaction between genetic variability of cultivars and fungal isolates on shoot biomass and on mineral status. Arbuscular mycorrhizal fungi can be ranked as *Glomus aggregatum* > *Glomus mosseae* > *Glomus versiforme* for improving yield as well as nitrogen, phosphorus, and potassium acquisition of *Solanum* cultivars.

Key words: Arbuscular mycorrhizal fungi, *Solanum aethiopicum*, sterile soil, relative mycorrhizal dependency.

INTRODUCTION

Solanum aethiopicum is a cultivated plant much appreciated by the urban and rural African populations. In order to enhance the yield of this plant with high added value, selected cultivars of *Solanum* adapted to the climatic conditions of the West-African region are being investigated by the Institut Sénégalais de Recherches Agricoles (ISRA). Unfortunately, most of the soils in the region are poor in phosphorus and in nitrogen, and the weak purchasing power of the most farmers does not allow them to buy artificial fertilizers.

Arbuscular mycorrhizal (AM) fungi are known to increase yield and mineral nutrition of associated plants. Therefore, efforts must be done to optimise the beneficial effects of AM fungi in sustainable agriculture (Gerdemann, 1968; Sieverding, 1991, Diop, 1996). AM fungi show little host specificity but the nutritional, physiological and growth responses as a result of the infection can differ considerably (Plenchette et al., 1983;

*Corresponding author. E.mail: Tahir.Diop@ird.sn.

Table 1. Effects of main factors on shoot dry matter (SDW) and mineral contents of *Solanum* cultivars after four months cultivation.

F1: "inoculation" factor	SDW (g)	N (mg)	P (mg)	K (mg)
Control	3.35c	63.37b	16.42c	130.56c
G. aggregatum	5.19a	115.22a	23.35a	210.51a
G. mosseae	4.78a	104.28a	19.60b	193.53a
G. versiforme	4.06b	73.95b	13.37d	154.55b
F2: "Cultivars" factor				
Cabrousse	3.18c	64.19d	13.52c	127.14c
L10	5.33a	110.64a	22.08a	210.76a
Sokhna	4.90a	98.26b	20.32a	192.46a
Keur Mbir	3.98b	83.72c	16.81b	158.78b

Values within columns with the same letter are not significantly different (P = 0.05) by the Newman-keuls test.

Ruiz-Lozano et al., 1995). Although the most species are colonized by the AM fungi, they are not necessarily infected by the most efficient ones. The knowledge of the best symbiotic partners could be a very promising solution towards sustainaibility.

In Senegal, AM fungi occurrence is widespread, diverse and can be found even in soil depths greater than 35 metres (Diop et al., 1994; Diallo et al., 2000; Dalpé et al., 2000). Conditions to produce and to preserve *in vivo* and *in vitro* AM fungi from Sahelian zones have been described (Strullu et al., 1996). However, experiments to assay agronomic value of indigenous AM fungi are few and limited. Most studies deal with temperate AM isolates. The present study was undertaken to evaluate the responses of *Solanum* cultivars, commonly grown in Senegal, to inoculation with selected indigenous AM fungi from Sahelian zones of Senegal.

MATERIALS AND METHODS

Fungal materials

Three AM fungi; *Glomus aggregatum* Schenck & Smith emend. Koske (DAOM 227 128), *G. mosseae* (Nicol. & Gerd.) Gerdemann & Trappe (DAOM 227 131), and *G. versiforme* (Karsten) Berch (DAOM 227 132) were used as inoculum. Fungal isolates were propagated in association with *Zea mays* in plastic pots containing 1.5 kg of sterile coarse sandy soil. After 3 months of cultivation in a glasshouse, *Z. mays* seedlings were harvested. For each AM fungus, inoculum consisted of a soil mixture (10 g/pouch) containing heavily colonized roots of *Z. mays*, spores and mycelium.

Seed germination, inoculation and growing conditions

Seeds of four cultivars of *S. aethiopicum* (Cabrousse, L10, Sokhna and Keur Mbir) were surface sterilized in hydrogen peroxide (15%) for 3 min., then washed in sterile distilled water. Seed germination occurred two days after incubation on water agar at 28°C in the dark. One pregerminated seed of each cultivar was planted in pot filled with 1 kg of a sterilised sandy soil collected at Sangalkam (50 Km from Dakar). Inoculation was simultaneously achieved at transplantation using 10 g of inoculum for each AM fungal isolate. The sandy soil was collected at Sangalkam, located at 50 km from Dakar. The chemical and physical characteristics of the soil were as follows: clay 5.4%; fine sand 89%; carbon 0.3%; total nitrogen 0.02%; total potassium 333.5 ppm; total phosphorus 41 ppm; avalaible phosphorus 2.1 ppm; magnesium 0.3 ppm, and pH 6.0 (H_2O).

Plants were grown in a glasshouse under a day/night cycle of 12/12h, 30/25°C, and 60% relative humidity. During the experiment, the pots were weighed daily and water loss was compensated for by top watering.

Experimental design and assessments

The experiment was arranged as a 4 x 4 random factorial design (4 *Solanum* cultivars, 4 inoculations (3 AM fungi plus a control) with 5 replicates. Harvest was made after 4 months and the roots washed clean with tap water. Root mycorrhizal colonization was estimated using the gridline-intersect method (Giovanetti and Mosse, 1980) after staining with trypan blue (Phillips and Hayman, 1970). Shoot dry weight was also recorded after oven-drying at 65°C for three days. Shoot mineral content (N, P, K) was determined using standard methods: colorimetry for nitrogen (after Kjeldahl digestion), phosphorus by the molybdenum blue procedure, and flame photometry for potassium. Relative mycorrhizal dependency (RMD) of *Solanum* cultivars was calculated by expressing the difference between shoot dry weight of the mycorrhizal plant and the shoot dry weight of the non mycorrhizal plant as a percentage of the shoot dry weight of the mycorrhizal plant (Plenchette et al., 1983).

The Newman-Keuls multiple range test (P<0.05) was used for statistical analysis. Data given at percentage values were first subjected to arcsine square root transformation.

RESULTS

Main factor effects

All three AM fungal isolates increased shoot dry weight and nutritional contents of *Solanum* cultivars (Table 1). *G. versiforme* isolate stimulated fewer growth parameters

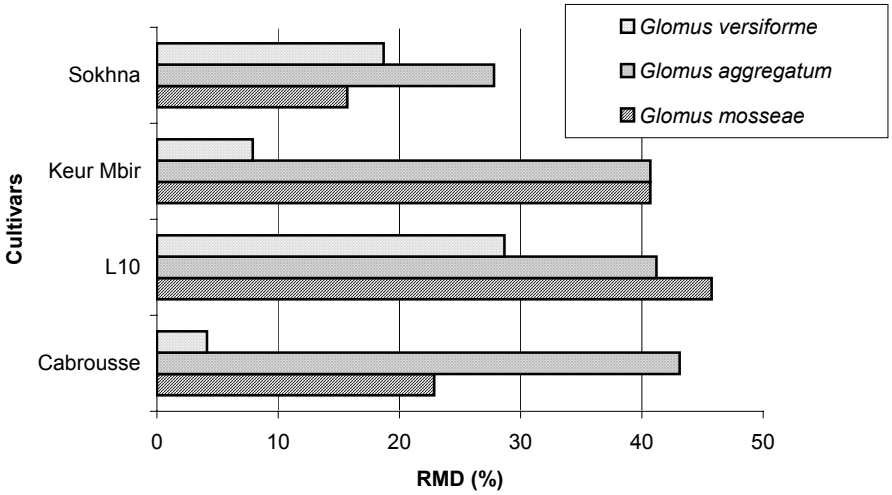

Figure 1. Relative mycorrhizal dependency (RMD) of four *Solanum* cultivars inoculated with three arbuscular mycorrhizal fungi (*G. aggregatum, G. mosseae,* and*G. versiforme*).

and did not influence phosphorus uptake compared to uninoculated plants. *G. aggregatum* and *G. mosseae* isolates were the most efficient fungi, and had the same stimulatory pattern, except for phosphorus content where *G. aggregatum* was more efficient than *G. mosseae*.

Genetic variability between *Solanum* cultivars was also observed (Table 1). The L10 and Sokhna cultivars showed higher shoot dry weight and mineral content. The Cabrousse cultivar had the lowest yield and nutritional status.

Mycorrhizal root colonization and relative mycorrhizal dependency

Establishment of AM fungi was effective within roots of all *Solanum* cultivars (Table 2). Typical AM fungal structures were regularly found in stained roots. More than 60% AM root colonization was estimated in cortical roots of all cultivars. Among the cultivars, L10 showed the highest percentage of root colonization with 90% after inoculation with *G. aggregatum*, 85% with *G. mosseae* and 75% with *G. versiforme*.

The relative mycorrhizal dependency (RMD) ranged widely among the cultivars tested (Figure 1). However, the calculated RMD was lower than 50% for all cultivars. The Keur Mbir and L10 cultivars showed the greatest dependency with *G. mossae* and *G. aggregatum*. The Cabrousse cultivar showed an intermediate dependency with only *G. aggregatum,* and Sokhna was the least dependent cultivar to all three AM fungal isolates.

Shoot weight and mineral content

The biomass of the Cabrousse cultivar was increased by inoculation with *G. aggregatum* and *G. mosseae* but not by *G. versiforme*. Inoculation by all three AM fungi significantly increased shoot dry weight of the L10 and Sokhna cultivars compared to control plants. *G. mosseae* and *G. aggregatum* induced the greatest biomass on L10 and Sokhna cultivars. For Keur Mbir cultivar, only *G. aggregatum* significantly increased biomass (Table 3).

Only *G. aggregatum* significantly increased shoot phosphorus content of all cultivars. *G. mosseae* only influenced phosphorus content of L10 compared to uninoculated control plants. *G. versiforme* had a negative effect on phosphorus uptake. *G. aggregatum* and *G. mosseae* increased shoot nitrogen and potassium of all cultivars, while *G. versiforme* only increased nitrogen and potassium uptake in the Sokhna cultivar.

Table 2. Percentage of root colonization of 4 *S. aethiopicum* cultivars inoculated with arbuscular mycorrhizal fungi after 4 months cultivation.

Cultivars	*G. aggregatum*	*G. mosseae*	*G. versiforme*
Cabrouse	75.50c	67.50b	62.00b
L10	90.00a	85.00a	75.00a
Sokhna	84.75b	80.00a	70.00a
Keur Mbir	75.00c	70.00b	65.00b

DISCUSSION

All AM fungi tested induced a higher degree of root colonization of *Solanum* cultivars. However, *G. versiforme* appeared to be less aggressive among the fungal isolates. Our results also confirm that genetic variability of plant cultivars can influence the efficiency of AM isolates (Declerck et al, 1995; Clark and Zeto, 2000).

Table 3. Effects of arbuscular mycorrhizal fungi on shoot dry matter (SDW) and shoot mineral mass of four *S. aethiopicum* cultivars. (Cont = Control, Ga = *G. aggregatum*, Gm = *G. mosseae* and Gv = *G. versiforme*).

Cultivars	SDW (g)				P (mg)				N (mg)				K (mg)			
	Cont.	Ga	Gm	Gv	Cont.	Ga	Gm	Gv	Cont.	Ga	Gm	Gv	Cont.	Ga	Gm	Gv
Cabrousse	2.63c	4.10a	3.42ab	2.56c	12.91b	18.4a	21.4b	8.70c	41.37c	90.91a	76.38b	48.13c	04.61c	164.62a	138.71b	100.61c
L10	3.71c	5.97b	6.47a	5.17b	18.17b	26.89a	26.54a	16.73b	73.04b	132.65a	144.39a	92.49b	147.26d	240.19b	262.24a	193.36c
Sokhna	4.03c	5.58a	4.78b	5.21ab	19.75b	25.10a	19.58b	16.85b	79.39c	123.82a	96.54b	93.28b	50.07c	231.71a	193.24b	194.83b
Keur Mbir.	4.00bc	5.11a	4.44b	3.32c	14.84c	23.00a	18.21b	11.19c	59.69b	113.5a	99.82a	61.90b	120.29c	205.50a	179.92b	129.40c

Means within a row followed with the same letter are not significantly different (P=0.05) by the Newman-Keuls test.

Growth and mineral nutrition of plants are commonly enhanced by inoculation with AM fungi (Diop, 1996; Clark and Zeto, 2000). Except for *G. versiforme*, our results confirm positive effects of AM inoculation on growth of the cultivars. Increase in growth and biomass of inoculated plants strongly depends on their ability to access minerals from the soil. Therefore, positive effects of tested AM fungi on phosphorus content could be related to the ability of symbiotic fungi to enhance soil P depletion zones around roots (Li et al., 1991; Clark and Zeto, 2000; Smith et al., 2001). The importance and function of extra- and intra-radical forms of AM fungal hyphae could also explain differences in P acquisition among AM isolates. Similar results had been found on soybean cultivars indicating that P uptake by mycorrhizal plants fluctuates with fungal isolates and genetic variability within cultivars (Khalil et al., 1994).

Nitrogen and phosphorus uptake of inoculated *Solanum* cultivars confirmed the role of genetic symbiotic factors in controlling translocation of mineral elements. It has already been demonstrated that extra-radical AM fungal hyphae are able to take up and transport N from soil to plants (Bago et al., 1996). Phosphorus and nitrogen uptake in *Solanum* cultivars, inoculated with *G. aggregatum* and *G. mosseae,* follow the same pattern. This is particularly important in leguminous plants which require high amounts of P and N to achieve biological nitrogen fixation (Barea et al., 1992; Diop et al., 2000). Potassium acquisition by *Solanum* cultivars was also improved by AM fungi even though *G. versiforme* only had a positive effect on K uptake of the Sokhna cultivar. The acidity of the Sangalkam soil could also explain the enhancement of K translocation to plants (Clark and Zeto, 2000).

The relative mycorrhizal dependency (RMD) refers to the degree of plant responsiveness to mycorrhizal colonization by producing maximum growth or yield at a given level of soil fertility (Gerdemann, 1975). Relative mycorrhizal dependency is related to morphological and physiological properties of root systems (Mosse et al., 1973; Gianinazzi-Pearson, 1984). Our study included a wide range of tested *Solanum* cultivars. Nevertheless, the calculated RMD was not above 50%. It has already been demonstrated, in soil with low available phosphorus, that plants develop numerous and longer root hairs (Bhat and Nye, 1973). *Solanum* cultivars bored profuse root hairs in our experimental soil that had low available phosphorus (2.1 ppm). Development of such fine-rooted systems could probably help *Solanum* to satisfy its growth over a relative short period, even though *G. aggregatum* and *G. mosseae* had a fairly high RMD on the L10 and Keur Mbir cultivars.

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