

Full Length Research Paper

Effect of arbuscular mycorrhizal fungi on the growth and development of maize (*Zea mays* L.) Grown in Bangui (Central African Republic) under controlled conditions

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The objective of this study was to evaluate the effects of arbuscular mycorrhizal fungi (AMF) on the growth and development of maize (*Zea mays*) in a greenhouse at the University of Bangui for three months under controlled conditions. Data collection was done at 30, 60 and 90 days after sowing (DAS) for growth parameters (plant height, crown diameter, number of leaves) and above-ground, root and total biomass were evaluated at 60 and 90 DAS. According to the results of this study, height growth showed a significant ($P < 0.05$) improvement of 106.7 cm when plants were inoculated with *Gigaspora rosea*. The treatment with the composite (G2+G3) showed higher diameter (15.50 mm), followed by the *Acaulospora laevis* strain with a diameter of 14.77 mm. The highest biomass values were obtained with the G4 mix strain (322.95 g for total biomass at 60 DAS and 535.44 g for total biomass at 90 DAS). From this study, it is evident that mycorrhizal fungi biofertilizers provide significant benefits to the plant, and can be used to improve corn growth and yield. Thus, this study could be further developed in the field.

Key words: Arbuscular mycorrhizal fungi, *Gigaspora rosea*, *Acaulospora laevis*, *Funneliformis mosseae*, growth, development, maize.

INTRODUCTION

Maize (*Zea mays* L.) is a tropical annual plant of the grass family. It is cultivated as a cereal for its starch-rich seeds, but also as a forage plant. The consumed part is the soft seed part, at the milky-doughy stage. The seed has a high energy nutritional value. The seed is also rich

in proteins and vitamins. It is the most cultivated cereal in the world (König, 2017). The economy of the Central African Republic (CAR) is largely based on the primary sector (agriculture, fishing, hunting, forestry). For three decades, the agriculture and livestock sub-sectors, which

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Table 1. Physico-chemical characteristics of the soil of Mbaïki.

Component elements	Content (100 g of sand)
Fine sand	36.02%
Medium sand	44.18
Coarse sand	15.10%
Silt	0.25%
Lilt	1.19%
Clay	3.25%
Organic material	0.232%
Total Carbon	0.134%
Total nitrogen	0.014%
C/N ratio	10
Assimilable phosphorus	53.76 ppm
Potassium	0.011 meq/100 g
pH (p/v : 1/2,5)	6.9

Source: Djamndo et al. (2021).

employ nearly 70% of the country's workforce and account for nearly 50% of gross domestic product (GDP), have experienced low average annual growth of around 2% (FAO, 2016).

In tropical agriculture, the management of natural soil fertility is one of the major challenges that agricultural operators must face on a daily basis in order to move this agriculture, which remains empirical and based on subsistence, towards an economic, more rational and income-generating agriculture. Currently, the living conditions of agricultural operators as a whole leave much to be desired, given that the yields they obtain from their crops remain at a low level and do not allow them to take up the challenge of food insecurity, which in principle is a very important factor if we want to get out of the poverty that the population of the CAR is facing on a regular and permanent basis. One of the main constraints to agriculture in Sub-Saharan Africa is the constant decline in the level of soil fertility, mainly nitrogen and phosphorus, resulting in a continuous decline in crop yields, including maize (Saïdou et al., 2012).

However, it is well established that maize is capable of forming a symbiosis with arbuscular mycorrhizal fungi (AMF) (Tchiegang-Megueni et al., 2000; Jemo et al., 2007; Benjelloun et al., 2014). In addition, the improvement of mineral element uptake (phosphorus and nitrogen), nutrition and growth of plants associated with mycorrhizae has been widely studied (Diatta et al., 2013; Haougui et al., 2013; Haro et al., 2015; Manga et al., 2017; Haro et al., 2020). Also, it has been shown that plant growth and production are enhanced by mycorrhizal symbiosis even when these plants are growing on relatively mineral-poor soils (Haro, 2016; Haro and Sanon, 2016; Haro et al., 2016a; Haro et al., 2017; Haro and Sanon, 2020). In CAR, no research has been conducted to date on the effect of AMF on crop growth and development to our knowledge. The objective of this

study was to evaluate the effects of AMF on the growth and development of maize under controlled conditions.

MATERIALS AND METHODS

Study area description

The trial was conducted in a greenhouse for three months in the experimental field of the liaison office of the Higher Institute of Rural Development Rural (HIRD) of Mbaïki located in the Faculty of Health Sciences (FACSS) of the University of Bangui (altitude: 436 m, latitude North: 4° 22'38" and longitude East: 18°33'37"). It consisted of growing maize in 10 L pots containing 7000 g of sterilized soil from Boukoko (Table 1). The plants were grown under the following conditions: average temperature 30/ 25.9 ± 2°C and relative humidity above 50%.

Plant and fungal materials

The plant material used for this study consisted of local white maize seeds obtained from the Centrafrican Institute of Agricultural Research (CIAR) in Boukoko (CAR). The fungal material was composed of three AMF inocula obtained from the International Bank for Glomeromycota (BIG) of the UMR 1347 Agroecology INRA/University of Burgundy/AGrSup, Dijon/France. These are the following AMF: G1: BEG 9 *Gigaspora rosea* LPA 23, G2: BEG 26 *Acaulospora laevi* LPA 25 G3: BEG 240 *Funnelformis mosseae* LPA 34 and G4: composite G2+G3.

Experimental design and set-up

The experimental set-up used was the one described by Haro and Sanon (2020) modified. The experimental set-up used was a simple randomized design. This setup is composed of 4 treatments [three inoculated treatments (G1, G2, G3 and G4mix) and one non-inoculated control] and each treatment is repeated 4 times.

Maize seeds were sanitized by soaking in half strength bleach (90%) for five minutes and then rinsed thoroughly with tap water before being soaked for thirty minutes in sterile water. The corn was sown at a rate of seeds per pot and the de-sowing was done in the first week after sowing so as to leave one plant per pot. The plants were grown in greenhouse for 90 days. The culture substrate was a sterilized soil (1 h at 120°C) from Boukoko whose physico-chemical characteristics were recorded in Table 1.

Inoculation of corn plants

The inoculation of these different strains of AMF was done one week after sowing. The mycorrhizal inoculum consisted of a mixture of spores, fungal propagules, fragments of mycorrhized roots and soil. The inoculum supply was 10 g or one teaspoon per plant (pot) with an average of 40 spores/g according to the dose used in sterilized medium (Boureima et al., 2007).

Measurement of parameters

Plant height measurements were taken in each experimental unit at 30, 60 and 90 days after sowing (DAS) using a tape measure. Neck (crown) diameter was measured with an electronic caliper at the separation zone between the root system and the aerial part at 30, 60 and 90 DAS. The number of leaves (NF) was counted on each plant at 30, 60, and 90 days of age.

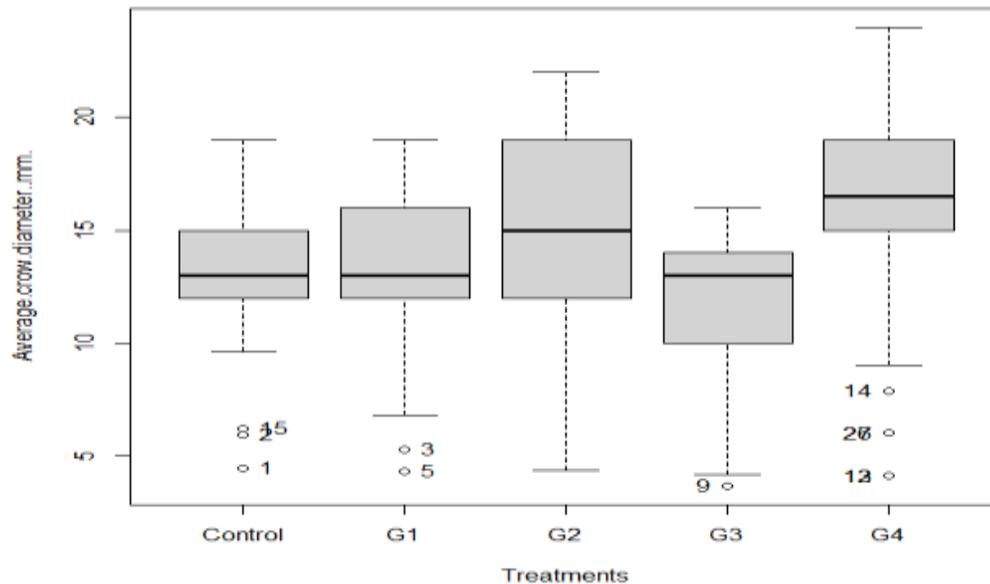


Figure 1. Effect of mycorrhizal inoculation on height growth of maize plants at 30, 60 and 90 days after sowing (DAS) inoculated with different arbuscular mycorrhizal fungal (AMF) strains. Control=not inoculated; G1: *Gigaspora rosea*, G2: *Acaulospora laevis*, G3: *Funneliformis mosseae* and G4: G2+G3.

The method used for the measurement of above-ground, root and total biomass was that described by Haro et al. (2020) modified. At 60 days after transplanting, each seedling was carefully stripped to recover the aerial part and all roots of the seedlings. All these parts were oven-dried at 70°C for 72 h until a constant weight was obtained for measurement of above-ground, root, and total biomass. After biomass measurement, the roots were used for the study of mycorrhizal colonization.

Statistical analysis

All data obtained were analyzed by analysis of variance (ANOVA) using R software for Windows. Tukey's test was used to determine any significant difference between treatments at the $P < 0.05$ threshold. All experiments were performed in four replicates.

RESULTS

Effect of mycorrhizal fungi inoculation on growth of corn plants

Corn plant height varied among treatments with different strains of mycorrhizal fungi used (Figure 1). Statistical analyses showed significant ($P = 0.0001$) differences in height between inoculated and non-inoculated treatments. The average crown diameter of plants under the effects of the fungal strains studied was 13 mm. However, the G4 strain had higher (15.5 mm) diameter, followed by the G2 strain which had a diameter of 14.77 mm and finally came the other strains of AMF. The ANOVA performed shows a significant difference ($P < 0.05$) between inoculated and non-inoculated treatments between the

diameters at the neck of the plants (Figure 2).

Inoculation had no significant ($P = 0.0001$) effect on average leaf number. Treatment G4, G2 and as well as the control treatment have an equal average of 8 leaves, during the whole study period in terms of number of leaves, followed by G1 and G3 plants with an equal number of leaves (Figure 3).

Evaluation of above-ground, root and total biomass

Results indicated satisfactory vegetative development throughout the crop. No signs of necrosis or leaf loss were observed. For each plant, the weight of the aerial and root parts varied depending on the strain inoculated. The aerial, root and total biomass parts showed variability according to the different treatments (Table 2). The results showed significant differences between the different treatments ($P = 0.0001$). The highest values were obtained with the G4 mix strain (322.95 g for total biomass at 60 DAS and 535.44 g for total biomass at 90 DAS). It is noted that the G1 strain presented a low total biomass (200.34 and 252.06 g), respectively, 60 and 90 DAS compared to the other treatments (Table 2).

DISCUSSION

The main purpose of this work is to evaluate the comparative effects of AMF on the growth and development of the maize crop. Results on the effects of

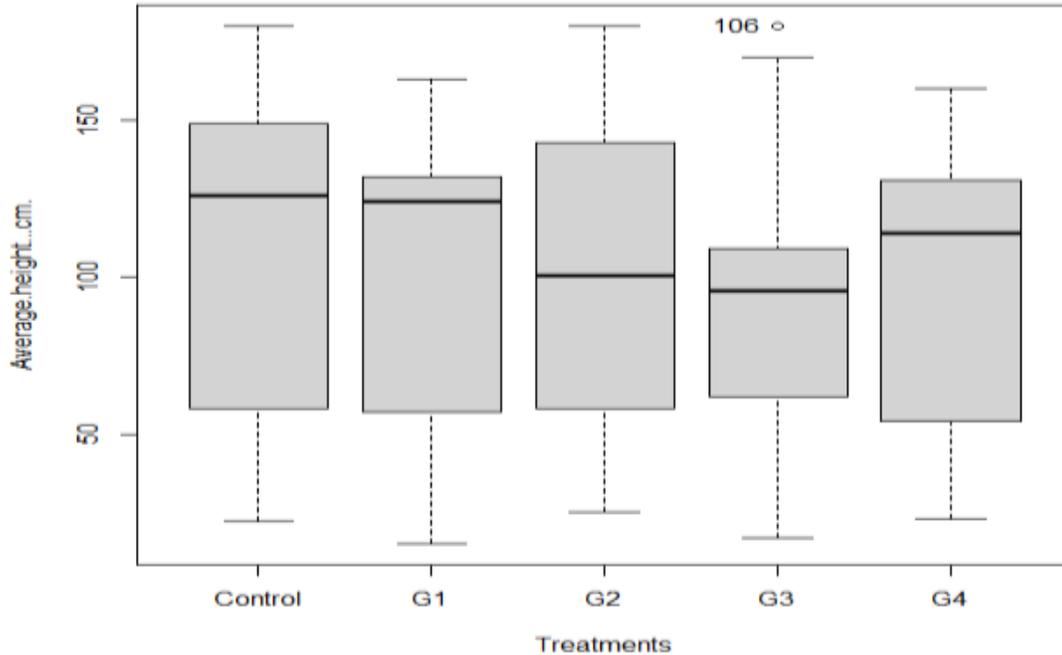


Figure 2. Effect of mycorrhizal inoculation on crown diameter of maize plants at 30, 60 and 90 days after sowing (DAS) inoculated with different arbuscular mycorrhizal fungal (AMF) strains. Control=not inoculated; G1: *Gigaspora rosea*, G2: *Acaulospora laevis*, G3: *Funneliformis mosseae* and G4: G2+G3.

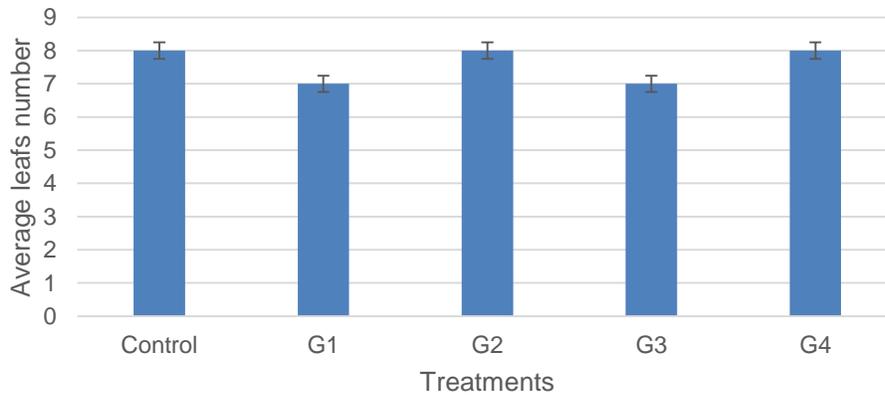


Figure 3. Effect of mycorrhizal inoculation on leaf number of maize plants at 30, 60, and 90 days after sowing (DAS) inoculated with different arbuscular mycorrhizal fungal (AMF) strains. Control=not inoculated; G1: *Gigaspora rosea*, G2: *Acaulospora laevis*, G3: *Funneliformis mosseae* and G4: G2+G3.

treatments on plant height growth, plant crown diameter, leaf number, and above-ground and root biomass in the vegetative phase of maize plants revealed that AMF had a beneficial effect.

As observed in maize, the supply of mycorrhizal inoculum results in the formation of mycorrhizal structures (De Alwis and Abeynayake, 1980; Lodge, 1987; Newbery et al., 1988; Béreau and Garbaye, 1994). All plants tested responded significantly to mycorrhizal

inoculation. The most significant results obtained with G3 and the G4 (G2+G3) composite on height growth of most plants were related to differential effectiveness of the strains for the plants tested. These results are similar to those of Caris et al. (1998) on groundnut (*Arachis hypogaea*) and sorghum (*Sorghum bicolor*) and Sulochana et al. (1989) on sesame (*Sesamum indicum* L.). The most significant results obtained with G1 and G2 on height growth and crown diameter on maize are

Table 2. Effect of mycorrhizal inoculation on root biomass, aboveground biomass and total biomass of maize plants at 60 and 90 DAS inoculated with AMF strains.

Treatments	Root biomass (g)		Aerial biomass (g)		Total biomass (g)	
	J60	J90	J60	J90	J60	J90
Control	39.82 ^d	66.4 ^d	132.1 ^d	150.21 ^d	171.92 ^e	216.61 ^e
G1	50.84 ^c	67.66 ^d	149.5 ^d	184.4 ^d	200.34 ^d	252.06 ^d
G2	73.88 ^a	82.17 ^b	314.49 ^a	381.25 ^b	388.37 ^b	463.42 ^b
G3	66.13 ^b	71.04 ^c	223.49 ^b	250.57 ^c	289.62 ^c	321.61 ^c
G4 mix	54.00 ^c	119.99^a	268.95 ^c	415.45^a	322.95 ^a	535.44^a

Control = not inoculated; D30= 30 DAS; D90= 90 DAS; G1: *Gigaspora rosea*, G2: *Acaulospora laevi*, G3: *Funnelformis mosseae* and G4: G2+G3. For the same column, values that share the same superscript(s) are not significantly different according to the Tukey test at the 5% threshold.

related to a differential effectiveness of the strains for the tested varieties. These results are similar to the work of Haro et al. (2012) on the response to mycorrhizal inoculation of four cowpea [*Vigna unguiculata* (L.) Walp.] varieties grown in Burkina Faso and Senegal.

The results of this study on the average number of leaves obtained were not significantly different with the tested strains and the control. These results are not similar to the work of Parvathi et al. (1985) and Daft and El-Giahmi (2006) who reported that the inoculation of plants with AMF leads to an improvement in nutrition and a more significant increase in the number of leaves. The application of AMF resulted in a significant increase in root biomass, above-ground biomass and total biomass in inoculated plants, compared to non-inoculated plants after 90 days of sowing. These results are in agreement with those obtained by Diop et al. (2013) who showed that biomass production of *Vigna* is enhanced by mycorrhizal inoculation. Similarly similar results were found by Haro et al. (2017) who showed that mycorrhizal inoculation of cowpea with native inocula improves biomass production and seed production yield of this plant.

Conclusion

In tropical agriculture, the management of natural soil fertility is one of the major challenges that agricultural operators must face on a daily basis in order to move from an empirical and subsistence-based agriculture to an economic, more rational and income-generating agriculture. The results of the vegetative growth and especially the dry and fresh biomass tests show that the AMF strains (*Gigaspora rosae*, *Acaulospora laevis*, *Funnelformis mosseae*) have a significant (positive) effect than the control treatment. Although variability is observed between the different growth parameters, the four AMF strains show interesting results adapted to the pedoclimatic conditions of the study site. Thus, microbial biofertilizers based on AMF could be recommended to producers on soils poor in mineral elements such as

phosphorus.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

- Benjelloun S, El Harchli EH, Amrani JK, El Ghachtouli N, Fiiikri Benbrahim K, El Yamani ET (2014). Study of the importance of mycorrhization in the synthesis of phenolic compounds in corn (*Zea mays* L.) under water stress conditions. Research Inveny. International Journal of Engineering and Science 4(12):43-49.
- Béreau M, Garbaye J (1994). First observations on the root morphology and symbioses of 21 major tree species in the primary tropical rain forest of French Guyana. Annales des Sciences Forestières 51(4):407-416.
- Boureima S, Diouf M, Diop TA, Diatta M, Leye EM, Ndiaye F, Seck D (2007). Effects of arbuscular mycorrhizal inoculation on the growth and the development of sesame (*Sesamum indicum* L.). African Journal of Agricultural Research 3(3):234-238.
- Caris C, Hordt W, Hawkins HJ, Romheld V, George E (1998). Studies of iron transport by arbuscular mycorrhizal hyphae from soil to peanut and sorghum plants. Mycorrhiza 8(1):35-39.
- Daft M, El-Giahmi AA (1976). Studies on nodulated and mycorrhizal peanuts. Annals of Applied Biology 83:405.
- De Alwis DP, Abeynayake R (1980). A survey of mycorrhizae in some forest trees of Sri Lanka. In: Mikola, P. (Ed.). Tropical mycorrhiza research. Clarendon Press, Oxford. pp. 146-153.
- Djamndo DM, Elian HDB, Diop Omokolo ND (2021). Diversity of arbuscular mycorrhizal fungi in the three agroecological zones of the Central African Republic. African Journal of Biotechnology, In Press.
- Diatta MB, Manzo OL, Diouf PRM, Diop T (2013). Effects of mycorrhizal inoculation on sesame (*Sesamum indicum* L.) under natural conditions. International Journal of Biological and Chemical Sciences 7(5):2050-2057.
- Food and Agriculture Organization (FAO) (2016). FAO-RCA country programming framework (CPF) 56 p.
- Haougui A, Souniabe PS, Doumma A, Adam T (2013). Evolution of endomycorrhizal fungi populations on weeds in four market garden sites in the Maradi region of Niger. International Journal of Biological and Chemical Sciences 7(2):554-565, DOI: 10.4314/ijbcs.v7i2.12.
- Haro H, Semde K, Bahadio K (2020). Effect of mycorrhizal inoculation with strains of arbuscular mycorrhizal fungi on the growth of *Mucuna pruriens* (L.) DC under controlled condition. International Journal of Biological and Chemical Sciences 9(3):14851493.
- Haro H, Sanon KB (2016). Cowpea yield improvement with indigenous symbiotic microorganisms in Burkina Faso. IAVAO/IESOL/LAPSE

- symposium "Biodiversity and ecological processes for sustainable agriculture in West Africa". Dakar, Senegal.
- Haro H (2016). Optimization of rhizobial and mycorrhizal symbioses to improve cowpea [*Vigna unguiculata* (L.) Walp.] productivity in Burkina Faso. Ph.D., University of Ouaga 1 Professor Joseph Ki-Zerbo. 241.
- Haro H, Sanon KB (2020). Response of sesame (*Sesamum indicum* L.) to mycorrhizal inoculation with strains of arbuscular mycorrhizal fungi indigenous to Burkina Faso. International Journal of Biological and Chemical Sciences 14(2):417-423. DOI: 10.4314/ijbcs.v14i2.9
- Haro H, Sanon KB, Blagna F, Fofana B (2016a). Effect of native arbuscular mycorrhiza fungi inocula on the growth of Cowpea [*Vigna unguiculata* (L.) Walp.] in three different agro ecological zones in Burkina Faso. Journal of Applied Biosciences 108:10553-10560. DOI: <http://dx.doi.org/10.4314/jab.v108i1.8>
- Haro H, Sanon KB, Krasova-Wade T, Kane A, N'Doye I, Traoré AS (2015). Response to double mycorrhizal and rhizobial inoculation of cowpea (variety, KVX396-4-5-2D) grown in Burkina Faso. International Journal of Biological and Chemical Sciences 9(3):1485-1493.
- Haro H, Sanon KB, Le Roux C, Duponnois R, Traoré AS (2017). Improvement of cowpea productivity by rhizobial and mycorrhizal inoculation in Burkina Faso. Symbiosis pp. 1-14. DOI: 10.1007/s13199017-0478-3
- Jemo M, Nolte C, Nwaga D (2007). Biomass production, N and P uptake of *Mucuna* after Bradyrhizobia and Arbuscular mycorrhizal fungi inoculation, and P application on acid soil of Southern Cameroon. Dordrecht: Springer Netherlands pp. 855-864
- König C (2017). Le maïs, une céréale aux grains précieux. 9 p. <https://www.futura-sciences.com/planete/dossiers/botanique-mais-cereale-grains-precieux-2346/>
- Lodge DJ (1987). Resurvey of mycorrhizal associations in the EL Verde rain forest in Puerto Rico. P. 127. In: Sylvia, D.M., Hung, L.L. and Graham, J.H. (Eds.). Proceedings of the 7th North American Conference on Mycorrhizae. Institute of Food and Agriculture Science, University of California, Gainesville.
- Manga A, Ndiaye F, Diop TA (2017). The shrub fungus *Glomus aggregatum* improves mineral nutrition of *Acacia seyal* subjected to progressive salt stress. International Journal of Biological and Chemical Sciences 11(5):2352-2365. DOI: <http://dx.doi.org/10.4314/ijbcs.v7i5.10>
- Newbery DM, Alexandre IJ, Thomas DW, Gartlan JS (1988). Ectomycorrhizal rainforest legumes and soil phosphorus in Korup National Park, Cameroon. New Phytologist 109: 433-450.
- Parvathi KR, Venkateswarlu K, Rao AS (1985). Proceedings of the Indian Academy of Science (Plant Science) 95:35.
- Saïdou A, Kossou D, Acakpo C, Richards P, Kuyper WT (2012). Effects of farmers' practices of fertilizer application and subsequent maize yield and nutrient uptake in Central Benin. . International Journal of Biological and Chemical Sciences 6(1):363-376.
- Sulochana T, Manoharachary C, Rama Rao T (1989). Growth response and root colonization in cultivars of sesame to VAM fungi. Current Science 589:519-520.
- Tchiegang-Megueni C, Nwaga D, Mapongmetsem PM, Lirawa P (2000). Effects of rhizobial and mycorrhizal biofertilizers on *Mucuna pruriens* (L.) DC (Papilionaceae) in greenhouse. Annales de l'Institut National de la Recherche Agronomique de Tunisie: Institut National de la Recherche Agronomique de Tunisie (INRAT).