ISSN impreso: 0258-5936
ISSN digital: 1819-4087
DOI: 10.13140/RG.2.1.4728.9845
http://dx.doi.org/10.13140/RG.2.1.4728.9845
Ministerio de Educación Superior. Cuba
Instituto Nacional de Ciencias Agrícolas
http://ediciones.inca.edu.cu

Short communication
POTENTIALITY OF ARBUSCULAR MYCORRHIZAL INOCULANTS APPLIED TO CASSAVA CROP (*Manihot esculenta* Crantz) IN KIBALA, ANGOLA

Comunicación corta
Potencialidad de los inoculantes micorrízicos arbusculares en el cultivo de la yuca (*Manihot esculenta* Crantz) en Kibala, Angola

José P. João[1]✉, Moniz P. Mutunda[2], Amílcar F. Taíla[3] and Ramón Rivera Espinosa[4]

ABSTRACT. Considering the existence of arbuscular mycorrhizal inoculants applied at low quantities to cassava crop (*Manihot esculenta Crantz*) and the high mycorrhizal dependence as well as the significance of this crop in Angola, it is essential to evaluate the effectiveness of such products in this country, as a way to obtain an efficient mycorrhizal symbiosis and its benefits on cassava plantations. An experiment was conducted on a Rhodic Distric Ferralsol, in order to appraise the effect of *Funneliformis mosseae* strain INCAM-2 compared with a control treatment, in a randomized block design with four repetitions and 32 plants per plot. The trial was carried out in a Kibala producers' farm, South Kwanza province, using Calohendo variety. The inoculant was applied at planting time by coating both propagule tips at the dose of 11,6 kg ha^{-1}. The application of *F. mosseae* provided significant increases (P<0,001) in every variable tested, achieving more vigorous and taller plants, their height raising about 21 %, whereas edible root yields rose from 14,4 mg ha^{-1} in the control to 33,6 mg ha^{-1} in the inoculated treatment and mycorrhizal spores improved eight times at harvest time, indicating the effectiveness of *F. mosseae* under these edaphic conditions. These results prove the potentiality of applying such mycorrhizal products to cassava crop in Angola.

Key words: Angola, arbuscular mycorrhizae, cassava

RESUMEN. A partir de la existencia de inoculantes micorrízicos arbusculares que se aplican en bajas cantidades en el cultivo de yuca (*Manihot esculenta Crantz*), de la alta dependencia micorrízica y de la importancia del cultivo en Angola, resulta de primer orden evaluar la efectividad de estos productos en el país, como vía para obtener una simbiosis micorrízica eficiente y sus beneficios en las plantaciones del cultivo. Se ejecutó un ensayo en un suelo clasificado como Ferralsol dístrico ródico, para evaluar el efecto de la cepa INCAM-2 de la especie de hongo micorrízico arbuscular *Funneliformis mosseae* en comparación con un tratamiento testigo, en un diseño de bloques al azar con cuatro repeticiones y 32 plantas por parcela. El ensayo se realizó en una finca de productores en el municipio de Kibala, provincia de Kwanza Sur, con la variedad Calohendo. El inoculante se aplicó en el momento de la plantación a través del recubrimiento de ambas puntas de los propágulos, en dosis de 11,6 kg ha^{-1}. La aplicación de *F. mosseae* originó incrementos significativos (P<0,001) en todas las variables evaluadas, obteniéndose plantas más vigorosas con mayor crecimiento e incrementos en altura de 21 %, los rendimientos en raíces comestibles se elevaron de 14,4 Mg ha^{-1} en el tratamiento testigo a 33,6 Mg ha^{-1} en el tratamiento inoculado y las esporas micorrízicas en cosecha se incrementaron ocho veces, indicando la efectividad de *F. mosseae* en estas condiciones edáficas. Los resultados dejan clara la potencialidad de la aplicación de estos productos micorrízicos en el cultivo de yuca en Angola.

Palabras clave: Angola, micorrizas arbusculares, yuca

[1] Facultad de Ciencias Agrarias de la Universidad José Eduardo dos Santos, Angola.
[2] Instituto de Investigación Agronómica, Angola.
[3] Finalista del curso Agronomía de la FCA de la UJOES, Angola.
[4] Instituto Nacional Ciencias Agrícolas (INCA), gaveta postal 1, San José de las Lajas, Mayabeque, Cuba, CP 32700.
✉ zecapedro2003@yahoo.com.br

INTRODUCTION

Cassava (*Manihot esculenta Crantz*) is the fourth largest consumed basic food product after rice, wheat and corn, taking up an important agricultural place in tropical climatic regions, not only for its use as a human (1) and animal (2) food[A], but also for its wide application in industry (3). Angola is the sixth largest cassava producer (5,1 %) of the world, with an average yield of 14 mg ha^{-1}, besides being an essential product of food security in this nation[B].

Even though this crop is adapted to drought conditions and low soil fertility, it requires the application of 40 to 60 mg ha^{-1} fertilizers from market centers to achieve high yields (4); however, expensive fertilizers prevent farmers' access to such resources, so production is low, since most growing areas are in farmers' hands in Angola[B] (5).

Cassava is mycotrophic par excellence (6) and although there are plenty positive experimental reports on arbuscular mycorrhizal fungal (AMF) strain inoculation (6, 7, 8), only a few results have been published of its applications at production scale (9), as effective inoculants applied in small quantities are unavailable (10).

In Cuba, efficient AMF strains are recommended according to soil environment (11), more specifically to soil reaction (12), and it has been found that an efficient strain applied under such conditions establishes an effective symbiosis with any mycorrhizal-depending crop (11).

In Angola, there are no previous reports on AMF effectiveness in this crop and taking into account its great mycorrhizal dependency as well as the potential benefits associated, its evaluation is of the first order.

MATERIALS AND METHODS

The experiment was conducted under field conditions at Almeida farm in Kibala municipality, South Kwanza province, on a Rhodic Distric Ferralsol (13). The soil had a slightly acid reaction with low contents of organic matter and exchangeable bases (Table I) as well as low fertility. The contents of resident mycorrhizal spores were also low.

Kibala municipality has a humid tropical climate characterized by alternating well-defined rainy and dry seasons, with annual rainfalls between 1000 and 1400 mm, March and November being the wettest months, with annual mean temperature values from 20 to 21 °C at an altitude of 1000-1500 m (14).

The experiment consisted of two treatments: one inoculated by INCAM-2 strain classified as *Funneliformis mosseae*, derived from the strain collection of the National Institute of Agricultural Sciences (INCA), and a non-inoculated one, in a randomized block design with four replicates within the period of February 2014 to February 2015.

Soil chemical analysis was performed according to the Analytical Techniques Manual for soil and leaf analysis, organic and chemical fertilizers (15), whereas AMF spores by a modified wet-decanting method[C].

None of the treatments received mineral fertilization or organic manure without irrigating. Planting frame was of 1 x 1 m and plots had 32 plants, 10 out of which were evaluated. Angolan Calohendo variety was used as planting material that is commonly employed in cassava flour production, an essential food diet in many regions of the country.

AMF strain was selected from soil characteristics (Table I), besides taking into account strain recommendations based on soil environment and reaction (12), as well as on the results of a previous comparison trial of AMF strains with *Canavalia ensiformis* under this soil condition.

[A]FAO. *FAOSTAT* [en línea]. 2013, [Consultado: 17 de enero de 2015], Disponible en: <http://faostat3.fao.org/home/index.html>.

[B]Ministério da Agrigultura. *Resultados da 1.ª Época e estimativas da Campanha Agrícola 2008/2009*. Projecto Portal do Governo, República de Angola, 2010.

[C] Herrera, R. A.; Ferrer, R. L. y Furralzola, E. *Estrategia de funcionamiento de las micorrizas VA en un bosque tropical. Biodiversidad en Iberoamérica: Ecosistemas, evolución y procesos sociales*. (ed. ser. Monasterio M.), (ser. Diversidad Biológica), Programa Iberoamericano de Ciencia y tecnología para el desarrollo, Subprograma XII, Mérida, 1995.

Table I. Chemical soil characteristics at experimental initiation* and "resident" AMF spore number (0-20 cm deep)

Type of soil	pH H_2O	OM (%)	P (mg kg^{-1})	Na+	K+	Ca^{2+}	Mg+	Spore number 50 g^{-1}
				($cmol_c$ kg^{-1})				
Rhodic Distric Ferralsol	5,8	1,30	58,5	0,12	0,3	2,3	0,63	50

*Average values of six samples

The inoculant at a concentration of 30 spores g^{-1} was applied by coating cassava propagule tips (10) at the dose of 11,6 kg ha^{-1}.

Plant height was evaluated every two months whereas edible root yield (mg ha^{-1}) of each plot was recorded after a year of being planted and at harvest time; in addition, composite rhizosphere soil samples (0-20 cm) were taken from calculation plants of each plot to determine mycorrhizal spores.

Treatment means were compared by Student T test (P<0,05) using SPSS Statistic program version 19 (16).

RESULTS AND DISCUSSION

Six months after crop cultivation, *F. mosseae* application always had significant effects on growth, yield and mycorrhizal spore production (Table II), its height increasing about 21 %, doubling its yield and raising mycorrhizal spore quantities approximately eight times, compared with the control. It should be noted that yields from the control treatment were similar to the average yields obtained in Angola[A], thus, supporting the experimental result.

Results indicated that *F. mosseae* behaved as an efficient strain under these soil conditions, validating Cuban recommendation of this strain to inoculate crops in soils with pH between 4,5 and 5,8 (12).

High values of spores of the inoculated treatment appear to be a consequence of *F. mosseae* effectiveness under these conditions, similar to what was found by other authors (17, 18) when inoculating the efficient AMF strain in various crops.

Therefore, it is necessary to optimize the amounts of fertilizers or organic manures along with the application of mycorrhizal inoculants, in order to ensure sustainability (8) and establish efficient strains for other soil conditions; these results indicate the benefits that can obtained by putting it into practice in Angolan agriculture.

CONCLUSIONS

- Results prove the feasibility and potentiality of using AMF inoculants in cassava crop in Angola.
- RECOMMENDATIONS
- To keep on investigating AMF inoculation in various crops and soils of Angola
- To extend relevant research results to production in Angola with this and other efficient AMF strains

BIBLIOGRAPHY

1. Centro Internacional de Agricultura Tropical (CIAT). *La Promesa de la Agricultura Tropical Hecha Realidad* [en línea]. Informe Anual CIAT 2012–2013, Inst. Centro Internacional de Agricultura Tropical (CIAT), Colombia, 2013, p. 47, ISSN 2145-1311, [Consultado: 10 de diciembre de 2015], Disponible en:<http://ciat.cgiar.org/wpcontent/uploads/2013/06/informe_anual_2012.pdf>.
2. Howeler, R. H. ''Cassava Leaf Production for Animal Feeding'' [en línea]. En: ed. Howeler R. H., *The Cassava Handbook. A Reference Manual based on the Asian Regional Cassava Training Course, held in Thailand*, edit. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 2011, pp. 626-648, [Consultado: 10 de diciembre de 2015], Disponible en: <https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwj6zui3h9LJAhUEFx4KHb2AC-YQFggfMAA&url=http%3A%2F%2Fciat-library.ciat.cgiar.org%2FArticulos_Ciat%2Fbiblioteca%2FThe%2520Cassava%2520Handbook%25202011.pdf&usg=AFQjCNGQ05XNRhYzHQkr82rI0Lqvf8Rxew&bvm=bv.109395566,d.dmo>.

Table II. Effect of applying *F. mosseae* on height, edible root yields and mycorrhizal spores of cassava plantation

	Height (cm)					Yield	Spore number
	4 months	6 months	8 months	10 months	12 months	mg ha^{-1}	g^{-1} de suelo
F. mosseae	66,88	101,97 a	134,00 a	187,25 a	219,25 a	33,59 a	49,94 a
Control	67,57	84,47 b	112,16 b	137,97 b	181,07 b	14,39 b	6,12 b
F	0,121	44,544	93,862	131,920	20,288	261,086	333,10
P	0,740	0,001	0,000	0,000	0,004	0.000	0,000

3. Ospina, P. B.; Gallego, C. S.; Ospina, P. H. y Gil, J. L. ‘‘Use of Cassava for Small-scale Ethanol Production with Value-added By-products’’ [en línea]. En: ed. Howeler R. H., The Cassava Handbook. A Reference Manual based on the Asian Regional Cassava Training Course, held in Thailand, edit. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 2011, pp. 710–728, [Consultado: 10 de diciembre de 2015], Disponible en: <https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwj6zui3h9LJAhUEFx4KHb2AC-YQFggfMAA&url=http%3A%2F%2Fciat-library.ciat.cgiar.org%2FArticulos_Ciat%2Fbiblioteca%2FThe%2520Cassava%2520Handbook%25202011.pdf&usg=AFQjCNGQ05XNRhYzHQkr82rI0Lqvf8Rxew&bvm=bv.109395566,d.dmo>.
4. Howeler, R. *Sustainable soil and crop management of cassava in Asia*. vol. 389, edit. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 2014, 280 p., ISBN 978-958 -694-125-9.
5. Economic and Social Development Department. *FAO statistical yearbook* [en línea]. edit. Food and Agriculture Organization of the United Nations (FAO), Roma, Italia, 2010, [Consultado: 20 de marzo de 2016], Disponible en: <http://www.fao.org/docrep/015/am081m/am081m00.htm#Contents_ru>.
6. Sieverding, E. *Vesicular-arbuscular Mycorrhiza Management in Tropical Agrosystems*. edit. Bremer, 1991, 402 p., ISBN 978-3-88085-462-8.
7. Okon, I. E. ‘‘Field response of two cassava genotypes inoculated with arbuscular mycorrhizal fungus to *Gliricidia sepium* mulch in a Tropical Alfisol’’. *Botany Research International*, vol. 4, no. 1, 2011, pp. 04–08, ISSN 2221-3635.
8. Ceballos, I.; Ruiz, M.; Fernández, C.; Peña, R.; Rodríguez, A. y Sanders, I. R. ‘‘The *in vitro* mass-produced model mycorrhizal fungus, *Rhizophagus irregularis*, significantly increases yields of the globally important food security crop cassava’’. *PloS One*, vol. 8, no. 8, 2013, p. 70633, ISSN 1932-6203, DOI 10.1371/journal.pone.0070633.
9. Rivera, E. R.; Fundora, S. L. R.; Calderón, P. A.; Martín, C. J. V.; Marrero, C. Y.; Martínez, L. R.; Simó, G. J.; Riera, N. M. y Joao, J. P. ‘‘La efectividad del biofertilizante EcoMic® en el cultivo de la yuca. Resultados de las campañas de extensiones con productores’’. *Cultivos Tropicales*, vol. 33, no. 1, marzo de 2012, pp. 5-10, ISSN 0258-5936.
10. Ruiz, L. A.; Simó, J. y Rivera, R. ‘‘Nuevo método para la inoculación micorrízica del cultivo de la yuca (*Manihot esculenta* Crantz)’’. *Cultivos Tropicales*, vol. 31, no. 3, septiembre de 2010, pp. 15-20, ISSN 0258-5936.
11. Rivera, R.; Fernández, F.; Fernández, K.; Ruiz, L.; Sánchez, C. y Riera, M. ‘‘Advances in the management of effective arbuscular mycorrhizal symbiosis in tropical ecosystesm’’. En: *Mycorrhizae in Crop Production*, edit. Haworth Food & Agricultural Products Press, Binghamton, 10 de julio de 2006, pp. 151–196, ISBN 978-1-56022-307-8.
12. Rivera, R.; Gonzalez, P. J. y Hernández, J. A. ‘‘La importancia del ambiente edáfico y del pH sobre la efectividad y la recomendación de cepas eficientes de HMA para la inoculación de los cultivos’’. En: *VIII Congreso de la Sociedad Cubana de la Ciencia del Suelo*, edit. Instituto de Suelos, Ministerio de la Agricultura y Sociedad Cubana de la Ciencia del Suelo, La Habana, Cuba, 2015, ISBN 978-959-296-039-8.
13. IUSS Working Group WRB. *World Reference Base for soil resources 2014: international soil classification system for naming soils and creating legends for soil maps*. (ser. World Soil Reports, no. ser. 106), edit. Food and Agriculture Organization of the United Nations, Rome, 2014, 191 p., ISBN 978-92-5-108370-3.
14. Castanheira, D. A. *Características mesológicas de Angola*. 2.ª ed., edit. Missão de Inquéritos Agrícolas de Angola, Lisboa, 2006, 546 p., ISBN 972-8975-02-3.
15. Paneque, V. M.; Calderón, C. J.; Borges, A.; Hernández, T. y Caruncho, M. *Manual de Técnicas analíticas para Análisis de suelo, foliar, abonos orgánicos y fertilizantes químicos*. edit. Ediciones INCA, La Habana, Cuba, 2010, ISBN 978-959-7023-51-7.
16. IBM Corporation. *IBM SPSS Statistics* [en línea]. versión 19.0, [Windows], Multiplataforma, edit. IBM Corporation, U.S, 2010, Disponible en: <http://www.ibm.com>.
17. Espinosa, C. A.; Ruiz, M. L.; Rivera, E. R. y Espinosa, C. E. ‘‘Efecto del Nitrógeno y hongos micorrízicos arbusculares en dos clones comerciales de boniato sobre un suelo Pardo mullido carbonatado’’. *Centro Agrícola*, vol. 42, no. 2, 2015, pp. 39–46, ISSN 0253-5785, 2072-2001.
18. González, C. P. J.; Ramírez, P. J. F.; Morgan, R. O.; Rivera, E. R. y Plana, L. R. ‘‘Contribución de la inoculación micorrízica arbuscular a la reducción de la fertilización fosfórica en *Brachiaria decumbens*’’. *Cultivos Tropicales*, vol. 36, no. 1, marzo de 2015, pp. 135-142, ISSN 0258-5936.

Received: November 24th, 2015
Accepted: February 25th, 2016