**Cassava macro- and micronutrient uptake and partitioning in alley cropping as influenced by *Glomus spp.* in sub-humid tropics and its impact on productivity**

O.J. Oyetunji[1]; I.J. Ekanayake[2]; O. Osonubi[1]; O. Lyasse[2]
*[1] Department of Botany and Microbiology, University of Ibadan, Nigeria; [2] c/o VVOB Secretariat, P.O. Box 13322, Paramaribo, Suriname. E-mail: iekanayake@yahoo.com*

**Abstract**
The beneficial effects of arbuscular mycorrhizae (AM) on the macro- and micro-nutrient uptake and their partitioning in cassava (*Manihot esculenta* Crantz) under alley cropping were investigated in two sites in the derived savanna belt of Nigeria. Cassava was grown either between multipurpose trees species (*Leauceana leucocephala* and *Senna siamea)* in alley farming system or as a sole crop. AM species, *Glomus mosseae* and *G. fasciculatum* were used as the inoculum. Macronutrients were significantly partitioned to the shoot than the root, which was positively influenced by AM inoculation. The introduced AM fungi were able to enhance Fe, Zn, and Cu uptakes in field and in containers. Fe and Cu were significantly partitioned to roots while the tissue concentration of Zn was higher in shoots than in roots. AM fungi however did not significantly improve macro-nutrition. Introduction of exotic AM fungi can improve cassava micronutrient uptake under alley cropping where competition for nutrient uptake is strong. AM fungi had an overall beneficial effect on productivity of cassava under low fertility conditions.

**Introduction**

Soil degradation and nutrient depletion have increased and have become serious threats to agricultural productivity in sub-Saharan Africa (SSA). Arbuscular mycorrhizal (AM) fungi are crucial components of both plant and soil development and health because they act as mediators of nutrient transport from soil to plant and from plant to soil (Bethlenfalvay and Linderman 1992). AM fungi enhance nutrient uptake particularly P (Osonubi 1994) N, Zn, Cu and Fe (Faber *et al*. 1990). Cassava that is a dominant starchy staple in SSA is mainly cultivated in small farms in a variety of infertile soils without chemical fertilizer application (Asadu *et al*. 1998). An economically viable agronomic practice to sustain the long-term cultivation of cassava with adequate soil nutrients has to be put in place in the region. Cassava is highly responsive to AM infection and is noted as an obligatory mycorrhizal species (Read 1993). Therefore application of AM and fertilizer can boost its production. The objective of this study was to evaluate the contributions of VAM fungi and alley cropping system to cassava macronutrient and micronutrient uptake in order to formulate a strategy in years to come to create an enabling environment which promotes a balanced application of plant nutrients and higher productivity.


Fig. 1. Cassava/maize intercrop

**Materials and Methods**
Field layout and agronomy of the study, nutrient analyses, and statistical analysis is as described in Oyetunji et al. (2003):

**Results and Discussion**
Cassava roots were colonized by AM fungi (Figure 2) and the plots inoculated with the introduced AM fungus had greater percentage root colonization than the non-inoculated ones (Table 1).


Fig. 2. AM and water treatment on cassava roots and young tubers

Table 1: The percentage mycorrizal infection of cassava under the multi-purpose trees at Ajibode and cassava roots in sterilized soil

| Field or container trial | Percentage (%) root colonization | | | |
|---|---|---|---|---|
| | ***G. mosseae* inoculated** | | ***G. mosseae* non-inoculated** | |
| | **TMS 4 (2)1425** | **TME1** | **TMS 4 (2)1425** | **TME1** |
| *Multipurpose tree species* | | | | |
| *L. leucocephala* | 86.33a | 74.17b | 42.67c | 38.77c |
| *Senna siamea* | 65.53a | 82.65a | 23.44b | 36.3c |
| Leusenna | 69.71a | 72.48a | 35.76b | 40.65b |
| Sole | 77.5a | 72.9a | 36.15b | 31.3b |
| *Containers* | TMS 30572 | TMS 91934 | TMS 30572 | TMS 91934 |
| *Cassava* | 92.00a | 95.62a | 18.56b | 21.10b |

*Means are values of three replicates. Means followed by the same letter in a row are not significantly different at P <0.05. †Sole = without multipurpose tree species, ‡Leusenna = *Senna siamea and L. leucocephala* interplanted.

***Effect on micronutrients of cassava***: The effect of the exotic VAM fungi introduced was felt more on the uptake of the micronutrients at 6th month after planting (Table 2). At this stage cassava plants are actively translocating photosynthates to the enlarging tuberous roots. The uptakes of the microelements except Mn were significantly (P <0.05) higher in inoculated cassava than the non-inoculated. The increase brought about by VAM ranged from 26.8 to 49.3%. However, there was a significant reduction (27.5%) in Mn uptake of TME1. Data revealed that most of the microelements were significantly (P <0.05) partitioned to tuberous roots than the shoot. The percentage roots colonization of all the un-inoculated cassava plants were significantly lower than those inoculated with the exotic fungi. This shows that inoculation of cassava plants whether in the fields and in controlled environments with exotic AM fungi will always result in higher rates of root colonization in cassava. The Fe uptake of the inoculated TMS 30572 was significantly lower than the non-inoculated counterparts (832.3 and 710.4ppm/g respectively). The uptakes of Zn and Fe were significantly higher in the *G. fasciculatum* inoculated TMS 91934 than non-inoculated (Table 3). Only Zn was significantly partitioned to the shoot than the roots. Other three elements were partitioned to roots than shoots. Uptakes of Fe, Zn and Cu were improved by the introduced AM fungus in TMS 4(2) 1425 (improved cultivar) at 6 MAP. Enhancement of trace elements by AM was only reflected in two micronutrients: Zn (53%) and Fe (26.8%) in the landrace.

Table 2: The influence of *G. mosseae* on cassava clones TMS 4(2) 1425 and TME1 nutrient uptake (ppm/g) in Ajibode at 6 MAP.

| Treatment | ppm/g | | | |
|---|---|---|---|---|
| | **Mn** | **Cu** | **Zn** | **Fe** |
| *TMS 4(2)1425* | | | | |
| VAM | 422.2a | 22.42a | 78.08a | 721.6a |
| NVAM | 454.9a | 15.58b | 54.5b | 483.5b |
| Root | 592.45a | 27.22a | 58.8b | 591.8a |
| Shoot | 284.5b | 10.78b | 73.78a | 377.2b |
| *TME1* | | | | |
| VAM | 368.57b | 16.53a | 66.49a | 644.8a |
| NVAM | 469.8a | 1684a | 43.46b | 508.6b |
| Root | 515.25a | 22.7a | 37.27b | 605.2a |
| Shoot | 306.23b | 10.62b | 76.52a | 461.3b |

*Means are values of three replicates. Means followed by the same letter in a column are not significantly different at P <0.05. †VAM = Mycorrhizal inoculated, NVAM = Non inoculated

Table 3: The influence of *G. fasciculatum* on cassava clones TMS 30572 and TMS 91934 nutrient uptake (ppm/g) in sterilized soil at 6 MAP**.**

| **Treatment** | **ppm/g** | | | |
|---|---|---|---|---|
| **TMS 30572** | **Mn** | **Cu** | **Zn** | **Fe** |
| VAM | 276.4a | 30.69a | 42.11a | 832.3a |
| NVAM | 276.2a | 27.62a | 38.42a | 710.3b |
| Root | 439.5a | 47.63a | 25.7b | 1376.9a |
| Shoot | 194.8b | 20.3b | 48.01a | 453.5b |
| *Treatment main effect (P values)* | | | | |
| Trt | 0.05 | 0.92 | 0.03 | 0.89 |
| Plant part | 0.001 | 0.004 | 0.002 | <0.001 |
| Trt* Plant part | 0.96 | 0.39 | 0.0.925 | 0.04 |
| CV (%) | 17.25 | 31.29 | 24.69 | 12.79 |
| TMS 91934 | | | | |
| VAM | 449.3a | 19.7a | 73.61a | 831.73 |
| NVAM | 402.6a | 15.9a | 49.5b | 519.67b |
| Shoot | 295.38b | 10.7b | 75.15a | 499.80b |
| Root | 553.87a | 24.96a | 48.03b | 677.23a |
| *Treatment main effect (P values)* | | | | |
| Trt | 0.17 | 0.05 | 0.001 | 0.003 |
| Plant part | 0.001 | <0.001 | 0.002 | <0.001 |
| Trt* Plant part | 0.06 | 0.03 | 0.01 | 0.001 |
| CV (%) | 27.01 | 19.5 | 15.20 | 11.50 |

*Means are values of three replicates. Means followed by the same letter in column are not significantly different at P <0.05. †VAM = Mycorrhizal inoculated, NVAM = Non inoculated

The partitioning of elements was found to be influenced by both the AM and cassava component part. Fe and Cu were consistently partitioned more to roots than shoots and reverse for Zn. Partitioning was influenced by the presence of AM fungi. This was evident by significant P values (P< 0.001). The partitioning pattern in addition to their active role in plant growth and function could be attributed to the trace elements toxicity. When micronutrient level has reached a toxic level, the element could be diverted to the area where it could be stored with less injury to plant. Leaves require high rates of Zinc for protein synthesis. Roots are the sites of preferential copper accumulation when the external supply is large (Simwambana and Ekanayake 2001) while Mn is usually stored in plant leaves (Hughes and Williams 1988) a situation found in trial plants, as large amount of Mn was stored in the shoot and Fe uptake was reduced in some instances, while it was enhanced in most instances with the introduced AM fungi. AM fungi enhanced Zn and Cu uptake and the ambiguity found in Fe uptake might be due to the control excised by AM in its uptake to avoid toxicity.

***Macronutrients of cassava*****:** There were higher accumulations of microelements at 6 MAP (Table 4) in sterilized soil. In TMS 4(2) 1425 P and K uptakes were enhanced by AM. No significant difference was observed in Mg, N and Ca uptakes between M and NM of TMS 4(2) 1425 at 6 MAP, whereas in TME1, M plants accumulated more N, P, and Ca than NM plants. However, Mg and K uptakes were similar in both M and NM plants. The elements were accumulated significantly more in shoot than root in both cultivars at 6 MAP (Table 4). Uptake amount does not depend on percentage of AM infection but on effectiveness and efficiency of the strain in accumulating these elements. Results also revealed that the indigenous AM were effective in enhancing macro-element uptakes in cassava. AM development is shown to be greater in low-P fertile soils than high-P soils (Boerner 1986). Uptake of Ca in TME 1 and P in TMS 4(2) 1425 were significantly enhanced.

Table 4: The effect of *G. mosseae* inoculation on nutrient uptake (%) of two cassava cultivars TMS 4(2) 1425 and TME 1 in sterilized soil six months after planting (pot experiment 1)

| **Treatment** | **Percentage** | | | | |
|---|---|---|---|---|---|
| | **N** | **P** | **Ca** | **Mg** | **K** |
| TMS 4(2)1425 | | | | | |
| | *AM Treatment* | | | | |
| M | 2.58a | 0.24a | 2.80a | 0.82a | 1.86a |
| NM | 2.84a | 0.10b | 2.69a | 0.90a | 1.46b |
| | *Plant part* | | | | |
| Root | 1.60b | 0.10b | 1.97b | 0.96a | 1.32b |
| Shoot | 3.83a | 0.24a | 3.51a | 0.75a | 1.99a |
| TME 1 | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| *AM Treatment* | | | | | |
| M | 2.76a | 0.19a | 2.90a | 0.73a | 1.39a |
| NM | 2.29b | 0.13b | 0.76b | 0.76a | 1.32a |
| *Plant part* | | | | | |
| Root | 1.24b | 0.08b | 0.71b | 0.71b | 0.96a |
| Shoot | 3.90a | 0.21a | 0.78a | 0.78a | 1.18a |
| Treatment main effect (P value) | | | | | |
| Clone | 0.08 | 0.09 | 0.05 | 0.15 | 0.02 |
| AM Treatment | 0.03 | <0.001 | 0.01 | 0.07 | 0.001 |
| Plant part for TMS 4(2)1425 | 0.002 | <0.001 | 0.003 | 0.05 | 0.06 |
| Plant part for TME 1 | <0.001 | 0.005 | 0.01 | 0.08 | 0.02 |
| Interactive effect (P value) | | | | | |
| Clone * AM Treatment | 0.17 | 0.05 | 0.1 | 0.8 | 0.03 |
| AM Treatment * plant part | 0.01 | 0.03 | 0.001 | 0.003 | 0.02 |
| Clone * Plant part | 0.15 | 0.07 | 0.09 | 0.02 | 0.07 |
| CV (%) | 19.6 | 25.1 | 11.8 | 19.3 | 17.9 |

[A]M = mycorrhizal inoculated and NM = non inoculated
[B]Means in the same column followed by the same letter are not significantly different at P <0.05

The partitioning of the elements was found to be tissue dependent. All elements were significantly accumulated more in the shoot than the fibrous roots. This behavior can be attributed to higher rate of metabolism that requires the presence of these elements in the leaves while partitioning was influenced by AM. K appeared to be evenly distributed between the shoot and the roots. P and K uptakes were significantly higher in inoculated than in non-inoculated plants (Table 5). Other macronutrient uptakes were similar in both M plants and NM plants. The AM effect on TMS 4(2) 1425 and TME 1 were more apparent at 6 MAP. In the former, P and K uptakes were enhanced by the *G. mosseae* that was introduced and TME1 responded more to AM because P, N and Ca uptakes were higher in the M plants. *G. mosseae* continuously enhanced the Ca uptake in the landrace suggesting genotypic response to AM. The response of TMS 4(2) 1425 and TME 1 to AM in non-sterilized soil (at 6 MAP) did not differ from other results, except that P and K were significantly accumulated in AM inoculated TMS 4(2) 1425 and TME 1. The two cultivars increased their tissue concentrations of the macro-elements with age. At this 6 MAP the influence of AM inoculation on cassava nutrition was felt more concerning N and P uptakes both in sterilized and non-sterilized soils.

Table 5: The influence of *G. mosseae* inoculation on nutrient uptake (%/plant) of two cassava cultivars TMS 4(2) 1425 and TME 1 in non-sterilized soil at six months after planting (Pot experiment 2)

| **Treatment** | **Percentage** | | | | |
|---|---|---|---|---|---|
| | **N** | **P** | **Ca** | **Mg** | **K** |
| *TMS 30572* | | | | | |
| M | 2.68a | 0.21a | 2.80a | 0.83a | 1.61a |
| NM | 2.59a | 0.10b | 2.72a | 0.77a | 1.41b |
| *Plant part* | | | | | |
| Shoot | 3.86a | 0.226a | 3.86a | 0.72a | 1.88a |
| Root | 1.42b | 0.09b | 1.66b | 0.83a | 1.04b |
| *TMS 91934* | | | | | |
| M | 2.61a | 0.17a | 2.79a | 0.96a | 1.66a |
| NM | 2.46a | 0.13b | 2.66a | 0.88a | 1.36b |
| *Plant part* | | | | | |
| Shoot | 3.59a | 0.19a | 3.73a | 0.97a | 2.31a |
| Root | 1.58b | 0.12b | 1.68b | 0.85a | 0.62b |
| *Treatment main effect (P value)* | | | | | |
| Clone | 0.6 | 0.15 | 0.08 | 0.65 | 0.1 |
| AM Treatment | 0.13 | 0.07 | 0.09 | 0.06 | 0.01 |
| Plant part for TMS 4(2)1425 | 0.002 | 0.001 | <0.001 | 0.16 | <0.001 |
| Plant part for TME 1 | <0.001 | 0.003 | <0.001 | 0.9 | 0.002 |
| *Interactive effect (P value)* | | | | | |
| Clone * AM Treatment | 0.09 | 0.17 | 0.7 | 0.3 | 0.1 |
| AM Treatment * plant part | 0.02 | 0.03 | 0.005 | 0.15 | 0.001 |
| Clone * Plant part | 0.5 | 0.07 | 0.13 | 0.65 | 0.02 |
| CV (%) | 22.47 | 13.8 | 9.5 | 3.7 | 17.5 |

[A]M = mycorrhizal inoculated and NM = non-inoculated; The means are values of 3 replicates.
[B]Means in the same column followed by the same letter are not significantly different at P<0.05

It is apparent from above-described studies that cassava nutrient uptake partly depended on the efficacy of the associated AM fungi and nutrient status of soil.

**Acknowledgement**
The International Institute of Tropical Agriculture (IITA) funded this work. IITA Analytical Services Laboratory provided support for macronutrient and micronutrient assays.

## References

Asadu, C.L.A., Nweke, F.I., and Ekanayake, I.J. (1998). *Communications in Soil Science and Plant Analysis.* 29, 141-159

Bethlenfalvay, G.J. and Linderman, R.G. (1992) *Mycorrhizae in sustainable Agriculture*. ASA Spec. Publ. Madison. WI, USA. 124pp.

Faber, B.A., Zasoski, R.J., Munns, D.N., and Shackel, K. (1990).*Canadian Journal of Botany* 69**,** 87-94.

Hughes, N. P. and Williams, R. J. P. (1988). An introduction to manganese biological chemistry. In: *Manganese in Soils and Plants* (Eds. R. D. Graham, R. J. Hannam and N. C. Uren,.) pp 7-19.

Osonubi, O. (1994). *Biology and Fertility of Soil,* **18**, 55-59.

Oyetunji, O.J., Osonubi, O., and Ekanayake, I.J. (2003).*Journal of Agricultural Science*, *140* (3): 306-311.

Read, D. (1993) Mycorrhizas. In *Tropical soil biology and fertility*. A handbook of methods. (Eds. J.M. Anderson & J.S.I. Ingram). CAB International, UK, Second edition. pp. 121-131

Simwambana M.C.M. and Ekanayake, I.J. (2001). *Plant Biology 2001, Plant Biology Abstracts.* No. 0490. http: // www. Ryconuba.com/as.