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Morphological and structural diversities of indigenous endomycorrhiza communities associated to maize [*Zea mays* (L.)] in Northern Cameroonian soils

Tobolbai[1] R, Adamou[2] S, Ngakou[1]* A.
[1] *Department of biological Sciences, Faculty of Science, University of Ngaoundere, Laboratory of biodiversity and Sustainable Development. Biofertilizer and Bioinsecticide Unit, BP: 154, Ngaoundere, Cameroom*[2] *Department of Agriculture, Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon*
** Corresponding author, Email: alngakou@yahoo.fr*

Keys words: Adamawa, Far-North, North, *Zea mays*, endomycorrhiza, diversity, frequency, intensity, density, specific richness.

1 ABSTRACT

This study describes endomycorrhiza that enter into association with maize [*Zea mays* (L.)], **grown in northern Cameroon. During the survey, twenty seven (27) soil samples were collected from three northern Cameroonian regions. In each of the regions, nine (9) composite soils were sampled, thus 3 per department, corresponding to sampling sites, villages or localities. *Zea mays* seeds were grown in pots on the composite soils samples for 3 months. Parameters such as mycorrhizal frequency, intensity, specific density and specific richness were determined following to the standard methods. After spore extraction, species description and characterization were obtained through the informations provided by the International Vesicular Mycorrhizal fungi collection (INVAM): http://invam.caf.wv.edu/fungi/taxonomy/species ID.htm. Results indicate that the mycorrhizal frequency and intensity were respectively 20.5% and 15.38%. The highest specific endomycorrhizal density and richness were registered in the department of Diamare with 59.1% and 6% respectively. The morphological and structural characterization enabled the description of 6 endomycorrhizal species, belonging to 4 genera: *Glomus constrictum, Glomus maculosum, Glomus manihotis, Acaulospora kentinensis, Rhyzophagus intraradices* and *Diversispora epigae*. All the species were found in all composite soils sampled in all three *Zea mays* growing regions. These findings open opportunities for domestication and application of endomycorrhiza for a sustainable production of *Zea mays* in the field.**

2 INTRODUCTION

The northern regions of Cameroon (Adamawa, Far-North and North) are located in the Sudano-Sahelian zone, known for the severity of their climatic conditions and the low level of their soils fertility (Tsozue *et al.*, 2015). Several studies have shown that the potential contribution of Arbuscular Mycorrhizal Fungi (AMF) to soil can be critical in addressing this type of problems. In poor soils, several plant species are ecologically dependent on mycorrhizal fungi (Gemma *et al.*, 2002). These fungi are a major component of the soil microbial community that have successfully established a symbiotic relationship with two-thirds of plant species (Wang and Qui, 2006). AMF have been reported to improve the mineral nutrition of plants (Bago *et al.*, 2000), to promote their adaptations in polluted environments (Aloui *et al.,* 2009), and to help in controlling plant pathogens (Yao *et al.*, 2003; Li

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et al., 2006). In addition, AMF have shown to promote a marked improvement of soil structure (Caravaca *et al.*, 2002), or to enable the establishment of other beneficial microorganisms, including plant growth promoting rhizobacteria (Barea *et al.*, 2002). In the northern regions of Cameroon, cereals are the staple food (Ayongwa *et al.*, 2010). In these areas, a cereal such as *Zea mays* (L.) is a cultivar of choice. Hence, the study of the endomycorrhizal status associated to this plant can obviously be of great importance. Furthermore, ecological studies on the diversity of AMF elsewhere, whether they relate to the morphological characterization of spores, molecular biology techniques or endomycorrhizal inoculants tests in the field have been generally limited to exotic species, with little or no investigations on available native (indigenous) species (Moora *et al.*, 2004; Leal *et al.*, 2009; Symanczik, 2016). In this context, the main objective of this research was to determine the status of endomycorrhizal fungi associated to *Zea mays* grown in northern Cameroon. This work involves (a) the inventory of endomycorrhizae species associated to maize; (b) assessment of the distribution and diversity of the various species inhabiting the maize rhizosphere in the studied areas.

3 MATERIEL AND METHODS

3.1 Physical description of the study areas: The experiment was conducted in the three northern regions of Cameroon: Adamawa located in agro-ecological zone II (Guinean savanna type), Far-North and North located in agro-ecological zone I (Sudano -sahélienne type). Figure 1 illustrates the map showing the agro-ecological zones and the sampling localities.

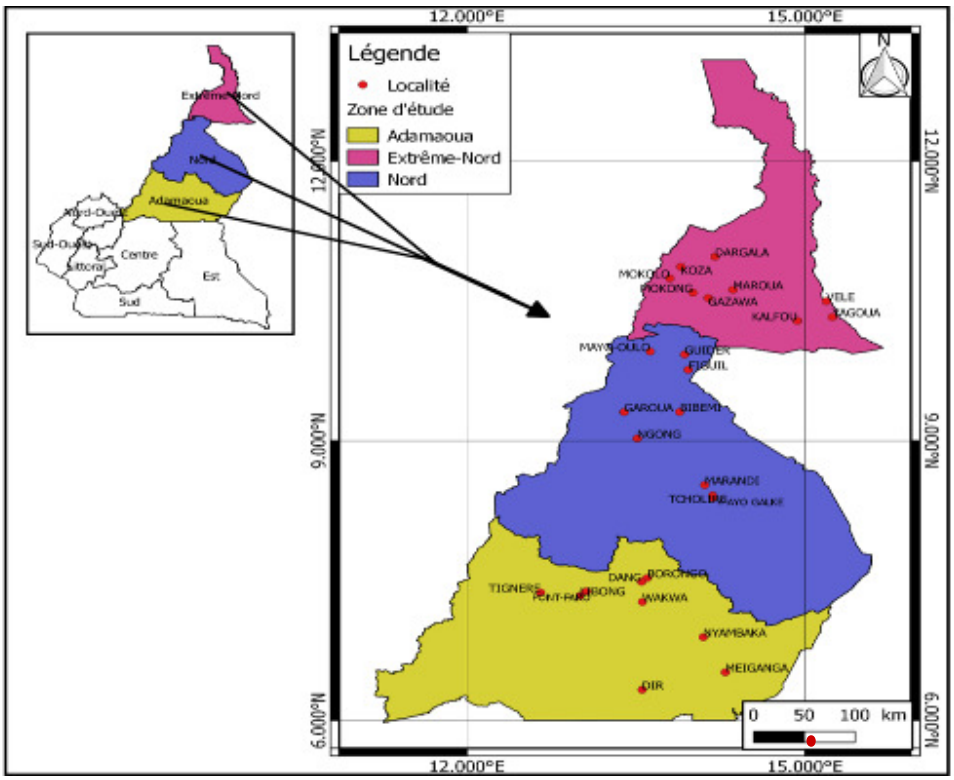

Figure 1. Map of the soil sampling sites and agro-ecological zones
In red and blue are respectively the Far-North and North regions within agro-ecological zone I; in yellow is Adamawa region within agro-ecological zone II

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3.2 Soil sampling: Soils were sampled at 3-10 cm depth after the surface was cleared from plant debris and other large particles. Sampling was carried out in three villages (localities) in each of the three departments of each region as summarized in table 1.

Table 1. Description of soil sampling sites

Regions	Departments	Localities	Altitudes (m)	Latitudes (°)	Longitudes (°)
Adamawa	Vina	Wakwa	1211	07.27041	13.55515
		Dang	1090	07.41049	13.54827
		Borongo	1155	07.46221	1359745
	Mbere	Meiganga	1011	0852444	14. 29010
		Babongo	1191	06.39133	14.09733
		Dir	918	06.32834	13.55277
	Faro-Deo	Tignere	1140	07.37072	12.65170
		Libong	958	7.33670	13.002410
		Pont-Faro	928	7.38352	13.05939
Far-North	mayo tshanaga	Mokong	326	10.58731	14.00415
		Mokolo	317	10.7412	13.7986
		Koza	371	10.86547	13.89596
	Riamare	Maroua	408	10.61877	14.35906
		Gazawa	482	10.53025	14.13976
		Dargala	357	10.53077	14. 93538
	Mayo Danaye	Kalfou	357	10. 28578	14. 93538
		Yagoua	357	10.32601	15.24176
		Vele	331	10.49614	15.18793
North	Mayo Louti	Mayo-Oulo	494	9.95649	13.62433
		Guider	384	9.92437	13.93035
		Figuil	298	8.76711	13.35941
	Benoue	Bibemi	247	9.30813	13.8870
		Ngong	326	9.02162	13.49671
		Garoua	295	9.31311	13.36625
	Mayo Rey	Mayo-Galke	311	8.38526	14.17865
		Tcholire	401	8.41254	14.17865
		Marandi	297	8.52431	14.10856

3.3 Determination of the physico-chemical properties of soils: The soils were analyzed at the Soil Water Analysis Laboratory of the Chadian Institute for Agronomic Research and Development. The assessed parameters were the particle size (sand, silt and clay content), the hydrogen potential (pH), the conductivity and the contents in organic carbon

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(OC), organic matter (OM), available phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca). These soil parameters were analysized by the PALINTEST Kit using a 5000 Direct Water Reading Proof Spectrophotometer that determines the soil physico-chemical properties. When choosing a test, the instrument automatically selects the parameters required for accurate analysis, including wavelength and reaction time. After the completion of the test, additional optional tests are available and the results can be converted into different units, depending on the studied parameter.

3.4 Trapping of endomycorrhizal spores from collected soil samples: Trapping of spore was carried out according to the method described by Brundrett *et al.*, (1996) modified as follows: *Zea mays* was sown in three different pots, each containing 1 kg of composite soil. The *Zea mays* seeds used were those of the local varieties and were graciously provided by the local farmers. The pots placed out of the contact with soil (Figure 2), were left at natural watering rainfall capacity for three months (July to September 2016). The roots of mature plants and rhizospheric soils were sampled for laboratory analysis. The roots in particular were preserved in the refrigerator at 4°C.

Figure 2: Trapping of endomycorrhizal spores using *Zea mays* as trapped plant

Fine harvested maize roots were thinned according to Phillips and Hayman (1970) method to highlight endomycorrhizal infestation structures. Roots were: (a) carefully washed, the youngest taken and cut to 1-2 cm in length; (b) put into a test tube with 10% potassium hydroxide, and heated in a water bath at 90 °C for 30 minutes to clear the roots; (c) the potash was discarded, filtered through a sieve, before neutralization by rinsing with acidified water; (d) neutralized roots were dept into cotton blue in a water bath for 15 minutes, filtered again through a sieve, and rinsed with distilled water; (e) some of these roots were mounted in water for direct observations, while other were mounted in glycerine for later observations. The mycorrhization estimation parameters were evaluated according to the formula of Sghir *et al.*, (2013). The frequency of mycorrhization F (%) was expressed as the percentage of colonization of the host plant roots by arbuscular fungi.

F (%) = 100 x (N-N0)/N, with N: the number of root fragments observed, and N0 the number of non-mycorrhizal fragments. The intensity of mycorrhization was refered to as the degree of roots colonized by arbuscular fungi and expressed as:

I% = (95n5 + 70n4 + 30n3 + 5n2 + n1)/N, where n5, n4, n3, n2 and n1 are the number of root fragments noted number 5, 4, 3, 2 and 1.

3.5 Extraction of endomycorrhizal spores from the composite rhizospheric *Zea mays* soils: Endomycorrhizal spores were extracted according to the wet extraction method described by Gerdemenn and Nicolson (1963) modified by the follows steps: (1) suspension of soil sample (500 g) in water; (2)

mechanical stirring of soil for 15 min (repeated thrice); (3) passing the soil through a series of sieves of size corresponding to the range of spores sizes of between [25 - 400 µm[; (4) creating a density gradient by centrifugation; (5) filtering through a 25 µm sieve for spores collection.

3.6 Morphological and structural Characterization of endomycorhizal spores in maize root: For the identification of AMF, the extracted spores were grouped by morphotype under criteria such as size, shape and color. Two groups of spores from each morphotype were mounted between slide and coverslip, thus one in PVGL (Polyvinyl-Lactic Acid-Glycerol), and the other in the PVGL-Melzer Reagent mixture (1:1/v:v) (Koske and Tessier, 1983). The morphotypes determination of the genus was made based on the classifications described by Morton and Benny (1990). The original descriptions of species, as well as the descriptions provided on the website of the International Vesicular Mycorrhizal fungi collection (INVAM): http://invam.caf.wv.edu/fungi/ taxonomy/species ID.htm were used as the reference during the identification process. Morphological characters of spores were compared with those of standard specimens and the reference strains. Several parameters were used to characterize AMF spores and were evaluated based on the formula proposed by Sghir *et al.*, (2013). The species richness refers to the total number of different morphotypes recorded in a 100 g soil sample, and was expressed by:

R (%): N/100g, where N is the number of different specimens.

The specific density indicates the number of spores recovered in 100 g soil sample, and was express as:

D (%): N / 100g, where N is the number of spores.

The diversity of endomycorrhizal species in all the sites was calculated using Shannon-Weaver diversity index (H) (Shannon, 1948). The Shannon index is given by the formula below:

$-H = -\Sigma p_i \ln pi$, where pi = S/N, S is the total number of individuals of one species, N is the total number of all individuals in the sample and ln = logarithm to base e. The proportion of species relative to total number of species (pi) was calculated, and multiplied by natural logarithm of this proportion (ln pi). The results were summed across the species, and multiplied by -1.

3.7 Data analysis: Data were statistically analyzed using a Statgraphic computer program, following data saving with Microsoft Excel. The Analysis of Variance (ANOVA) was used to compare different treatments, while segregation among means was achieved through the Least Significant Differences (LSD).

4 RESULTS AND DISCUSSIONS

4.1 Differences in the physico-chemical properties of composite soils of the sampling sites: Composite soil samples from different departments had varying physico-chemical properties (Table 2). The pH of all the sampled soils were acidic, in the range of 4.32-5.30. The lowest and highest pH values were recorded respectively in the soils of the departments of Faro-Deo (4.32) and Mayo Louti (5.30). Phosphorus content was higher in the department of Diamare (94%), while the poorest soil content in P was that of Faro-Deo.

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Table 2: Physico-chemical properties of sampled soils

	P^{H}	Sable (%)	Limon (%)	Clay (%)	Conductivity (µS/cm)	C.O (%)	M.O (%)	P (ppm)	K (ppm)	Mg^{2} (ppm)	Ca (ppm)
Vina	5.00cd	20.28b	23.52e	56.19i	212d	0.055a	0.095a	94g	330a	185f	1000e
Faro-Deo	4.32a	46.74e	10.78a	42.47f	152,1a	0.065a	0.112a	17a	560d	125d	500b
Mbere	4.92b	35.89d	23.66f	40.44e	271h	0.061a	0.105a	26b	450c	95b	1500f
Mayo Tshanaga	5.13d	73.20i	14.84c	11.95a	150,4a	0.067a	0.116a	43c	405b	60a	750d
Diamare	5.02bcd	12.86a	42.62h	44.55g	166,4b	0.061a	0.105a	72e	560d	410g	520c
Mayo Danay	4.97bc	27.78c	25.69g	46.32h	238f	0.066a	0.114a	43c	365a	115c	500b
Mayo Rey	5.02bcd	71.52h	15.68d	12.79b	232e	0.065a	0.112a	56d	450c	95b	2500h
Benoue	4.98bcd	71.10g	14.00b	14.89c	250g	0.065a	0.113a	30b	450c	180f	1750g
Mayo Louti	5.30 e	57.45 f	15.60d	26.93d	175,2c	0.066a	0.114a	86f	430c	135e	1750a
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<1,0000	<1,0000	<0.0001	<0.0001	0.0001	<0.0001
LSD	6.89	52.22	24.66	34.33	217.66	0.28	0.40	58.14	462.73	166.37	122.67

In the same column, the assigned values of the same letter are not significantly different at the indicated threshold.

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4.2 Frequency of mycorrhization in *Zea mays* within the departments of each region: Mycorrhizal frequency refers to the percentage of plant roots infested with arbuscular fungi. The frequency of mycorrhization was higher in the department of Faro-Deo (10%), compared to that of Mbere (4%) and Vina (1.66%) in the Adamawa region (Figure 3). In the Far-North region, the mycorrhization rate in Mayo Tshanaga (20%) was significantly higher ($p < 0.0001$) than that of Diamaré (2%) and Mayo Danay (1%) departments. In the North, although the frequency of mycorrhization differed from one department to another (Figure 3), it was not significant ($p = 0.1781$), with respectively 4.33%), 3.66%, 4.66%) in the departments of Mayo Rey, Benoue and Mayo Louti. When the frequency of mycorrhization in *Zea mays* roots was compared all together in the departments, the Mayo Tshanaga and Faro-Deo, respectively in the Far-North and Adamawa regions had the highest frequencies, the lowest accounting for the departments of Mayo Danay and Vina in the same respective regions.

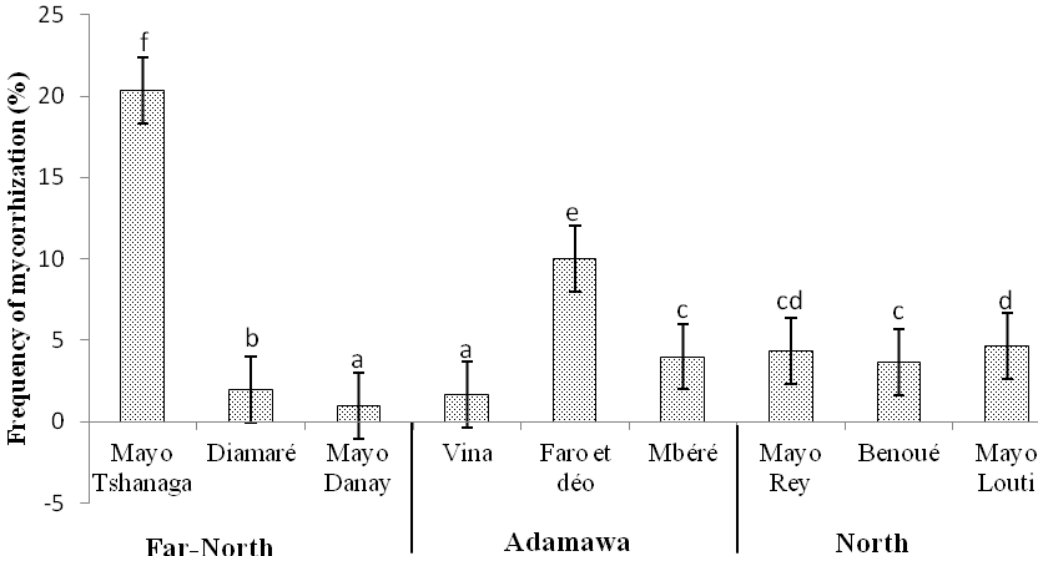

Figure 3: Variation of the frequency of mycorrhization in *Zea mays* roots within departments of each region.

For each region, values of the frequency of mycorrhization are means from three replicates. Bars affected by the same letter are not significantly differents at the indicated level of probability.

The variation of mycorrhization frequencies in different composite soil samples was previously observed by Sghir *et al.* (2013), who recorded various mycorhization frequencies in *Olea europa* spp in Morocco. The frequency of mycorrhization within the nine departments fall between the range of 1.66-20.5%, with values lower than those obtained by Houngnandan *et al.* (2009) in Benin, who reported the mycorrhization frequency of between 53.58% and 63% in *Zea mays* rhizosphere. The low rate of mycorrhization recorded in some of our studied sites could be attributed to the land use patterns (soils), especially ploughing, crop rotation and pesticide application (mostly fungicides) that negatively affect the AMF communities, thus the frequency of mycorrhization, through substantial decrease in mycorrhizal soil potential (Jansa *et al.*, 2014).

4.3 Intensity of mycorrhization in *Zea mays* roots within the departments of each regions: Figure 4 indicates different degrees of mycorrhizal colonization of plant roots in different regions. In the Adamawa region, the

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intensity of mycorrhization in maize root was significantly ($p < 0.0372$) higher in the Faro-Deo department (9.03%) than those of Mbere (3.48%) and Vina (1.41%). Instead, it is the department of Mayo Tshanaga (15.38%) that showed the significant ($p < 0.0001$) best intensity of mycorrhization in the Far-North compared to the departments of the compared Diamaré (1.4%) and Mayo Danay (1%). In the North, there was no significant difference ($p = 0.252$) between the intensities recorded in the three departments, Benoue Mayo Rey and Mayo Louti.

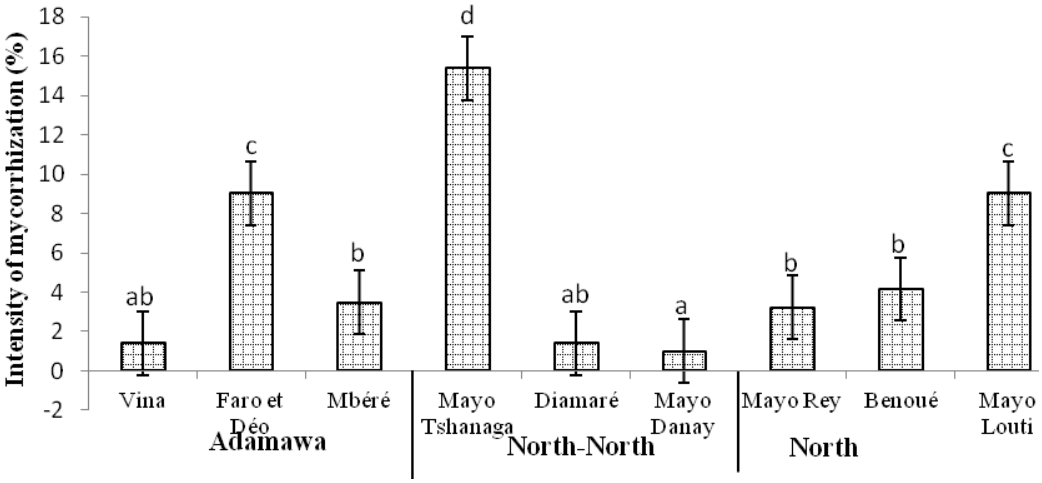

Figure 4. Intensity of mycorrhization in *Zea mays* within the departments of Adamawa Far North and North regions.
For each region, intensity of mycorhization values are means from three replicates. Bars affected by the same letter are not significantly differents at the indicated level of probability.

When the intensity of mycorrhization was compared in all the departments of the three studied regions, the Far-North region had both the higher (department of Mayo Tshanaga), and lower (department Mayo Dana) values. The intensity of mycorrhization was different between departments, and was linked to the mycorrhization frequency. Hence, the highest intensities of mycorrhization were recorded in the departments with higher frequencies of mycorrhization. The explanation could be related to variation in the physico-chemical properties of the different composite soils, particularly the sandy nature of the soil that may be more favourable to AMF development. In fact, the Mayo Tshanaga soils that had the highest sand content (73.20%) as shown in Table 2, was found to have the highest frequency and intensity of mycorrhization as well. These findings are closed to other results reported by Houngnandan *et al.*, (2009) in Benin, where the native glomales of the *Isoberlinia doka* forest have revealed high mycorrhizal frequencies on elevated sandy substrates content. However, a lower intensity of mycorrhization between 22.12-24% was obtained in the Bambara groundnut rhizosphere (Soa and Mendong soils) in the Centre region of Cameroon (Temegne *et al.*, 2017), confirming the variation of AMF spores intensity with the soil type or origin.

4.4 Specific density in endomycorrhiza of the *Zea mays* rhizosphere within the departments of each region: Within the Adamawa region, the specific density in the department of Vina (91%) was significantly ($p < 0.0001$) lower that of Mbere (139%) and Faro-Deo (252%) as shown on Figure 5.

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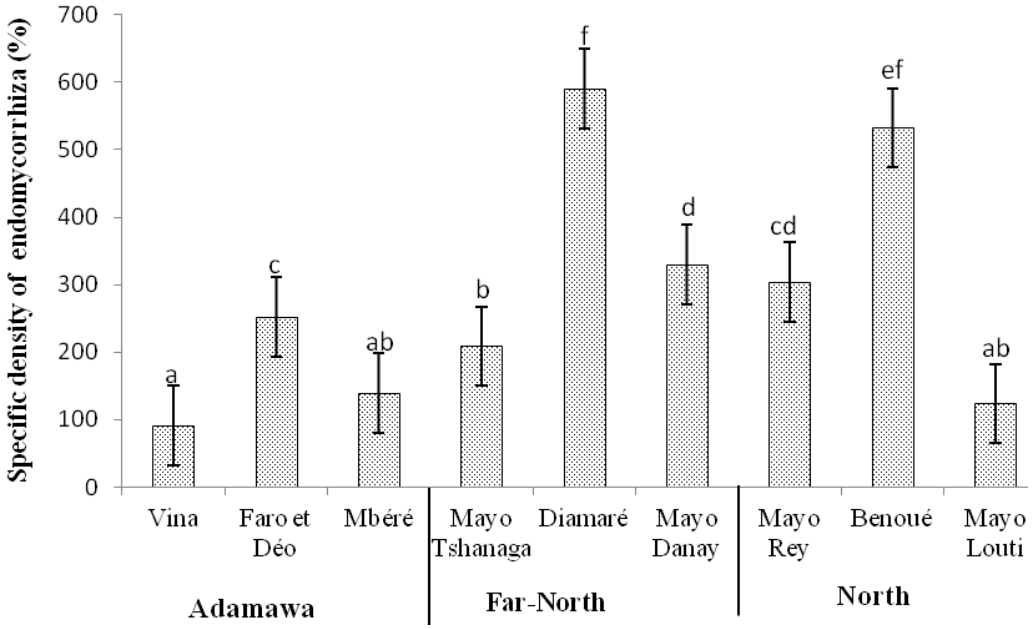

Figure 5: Variation of **the specific density of *Zea mays* in endomycorrhiza within the all the departments**

For each region, specific density values are means from three replicates. Bars affected by the same letter are not significantly differents at the indicated level of probability.

In the Far-North region, it was instead the department of Diamare (591%) that expresssed the highest significant ($p < 0.001$) specific density compared to that of the departments of Mayo Tshanaga (208%) and Mayo Danay (330%). As far as the North region is concerned, the specific density of mycorrhiza was consistently ($p < 0.0001$) lower in the department of Mayo Louti (121%), than those of Mayo Rey (304%) and Benoue (532%). The highest specific density in endomycorrhiza was recorded in the departments of Diamare, Faro-Deo and Benoue, respectively in the Far-North, North and Adamawa regions, whereas the lowest was recorded in the department of Vina in the Adamawa region. The obtained values are above those reported by Voko *et al.*, (2013) in southern-east of Ivory Coast, where the specific density of AMF in the cassava rhizosphere of four different fields was revealed to fall between 8.42-14.69%. In contrast, values that are more elevated revealed by Nouain (1994) in Morocco, who found AMF spores density between 900-2080% associated to *Argania spinosa*. This variation in spore density could be explained by differences in the physico-chemical properties of the composite soils of the different departments. In fact, the lowest specific density was that of the department of Vina, which had the highest phosphorus content that has been reported to limit the development of AMF in soils (Kowalska *et al.*, 2015). Conversely, higher endomycorrhiza spores density was also recorded in the department of Diamare, despite the relatively high content of its soil in phosphorus, indicating the tolerance of AMF spores to high levels of phosphorus. These observations line with other results pointed out by Begoude *et al.* (2016) that indicated low specific densities of AMF in plots of land with high phosphorus content (inoculated with NPK) and high densities in low phosphorus plots (non-inoculated NPK plots). In addition, spore density and AMF colonization were shown to decrease with increasing of fertilizers

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doses application, 10 g compost application/pot resulting to higher spore density and AMF colonization (Asrianti *et al.*, 2016). Previous research have shown that the availability of high soil phosphorus strongly have a negative effect on AMF development (Beenhouwer *et al.*, 2015). In addition, P fertilization with dose and high solubility have been reported to change the abundance, colonization and effectiveness of AMF propagules (Bhadulung *et al.*, 2005), with AMF tending to associate to low nutrient content, especially that of P (Smith and read, 2008; Heijden *et al.*, 2006).

4.5 Specific richness of *Zea mays* rhizosphere in endomycorrhiza within departments of each region: The species richness indicates the number of different AMF species in 100 g of soil. In the Adamawa region, the specific richness of endomycorrhiza was significantly lower ($p = 0.05$) in the department of Faro-Deo (3%), than in other departments such as Vina (4%), and Mbere (4%) (Figure 6). In the Far-North, the department of Diamare (6%) showed a significantly ($p < 0.048$) elevated specific richness of endomycorrhiza compared to that of Mayo Tshanaga (3%) and Mayo Dany (5%). In the North, although the specific richness of endomycorrhiza was greater in the department of Mayo Louti (3%) than those of Mayo Rey (2.66%) and Benoue (3.33%), this was not significantly ($p = 0.813$) enough. The species richness of endomycorrhiza in the *Zea mays* rhizosphere ranged from 3 to 6% between the departments, with the highest value allocated to the department of Diamaré in the Far-North, whereas the lowest was recorded in the department of Mayo Rey in the North.

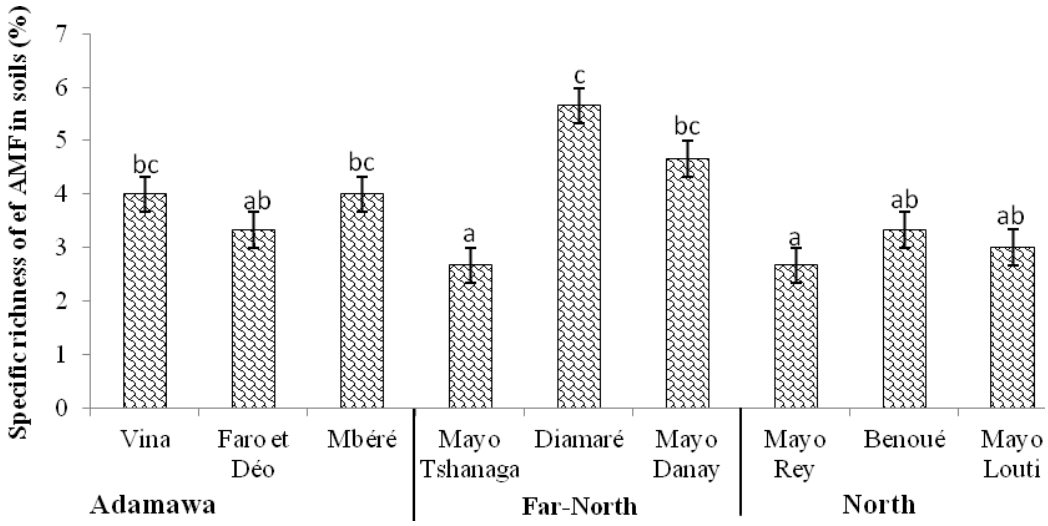

Figure 6: Variation of **the specific richness of Zea mays in endomycorrhiza within the all the departments**
Values are means from three replicates. Bars affected by the same letter are not significantly differents at the indicated level of probability.

These low values could be explained by the constant disturbance of cultivated areas by ploughing, crop rotation and pesticide application in the soil. These practices have been reported to create changes in the AMF populations structure (Jansa *et al.*, 2002), resulting in the elimination of certain key families such as Acaulosporaceae and Gigasporaceae, and hence, the decline in species richness. Moreover, AMF exhibit an asexual reproduction mode (Sander *et al.*, 2002), therefore, a single spore can infest several

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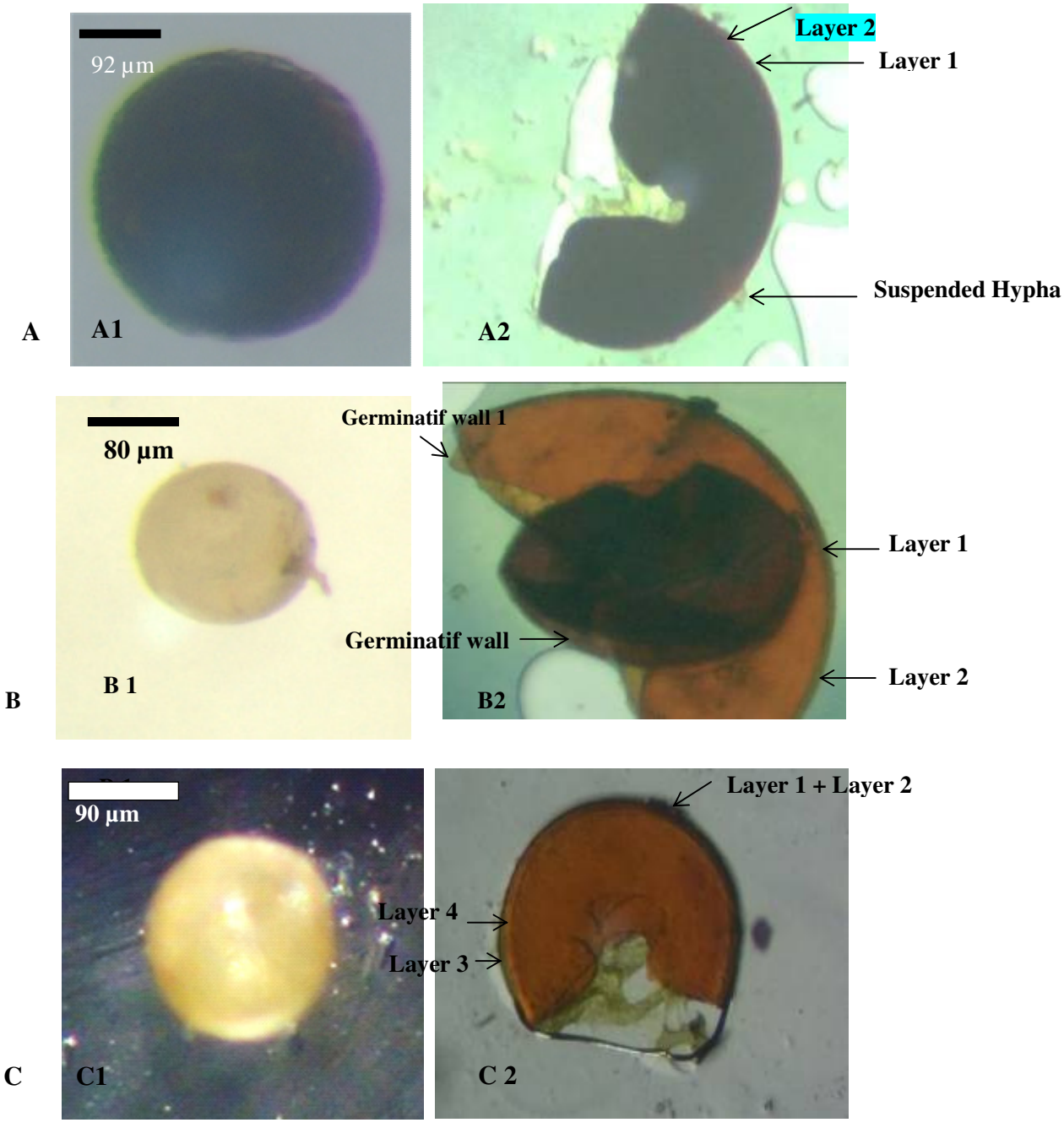
plants. Similar results were observed by Zhao *et al.*, (2003) at Xishuangbanna in southwestern China, where 525 spores were obtained from 118 soil samples collected, and were grouped into only 5 genera of which were *Glomus* (13 species), *Acaulospora* (9 species), *Gigaspora* (1 species), *Sclerocystis* (3 species) and *Scutellospora* (1 species).

4.6 Morphological and structural characterization of isolated endomycorrhizal spores: Morphological and structural analysis of isolated AMF spores have revealed the presence of six AMF species grouped into four genera. Figure 7 describes the various AMF species identified.



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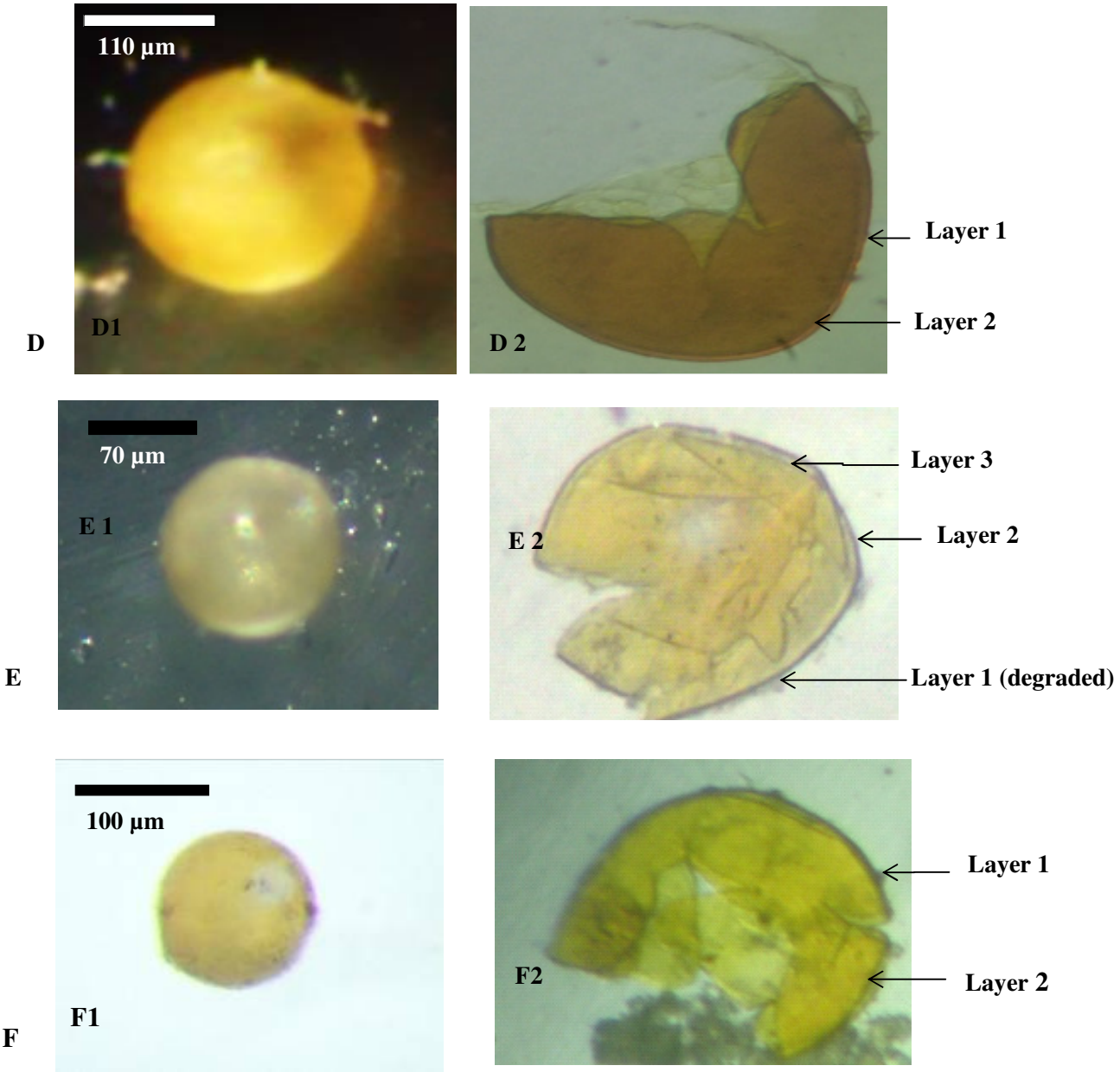

Figure 7: Morphological and structural diversity of isolated spores
A: *Glomus constrictum*, Trappe, (1977);
B: *Acaulospora kentinensis*, Kaonongbua *et al.*, (2010);
C: *Glomus maculosum*, Mill and Walker, (1986).
D. *Glomus manihotis*, Schenk *et al.*, (1984).
E. *Rhisophagus intraradices*, Schenk and Smith, (1982);
F: *Divesispora epigae*, Walker and Schubler, (1979).

On the overall, six (6) species of endomycorrhiza belonging to four genera were found in Northern Camerounian soil samples based on morphological characterization: *Glomus* (3 species); *Acaulospora* (1 species); *Divesispora* (1 species); *Rhisophagu* (1 species). In a similar research, three genera of arbuscular mycorrhizal fungi were found, namely *Glomus,*

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Gigaspora and *Acaulospora*, with *Glomus* recorded as the dominant species (Asrianti *et al*., 2016). This study has revealed Shannon-Weaver diversity index of 0.48, which is very low, suggesting that there are few successful endomycorrhiza species in northern Cameroonian soils.

$H' = [(2605/2823)x\log_2(2605/2823) + (7/2823)x\log_2(7/2823) + (7/2823)x\log_2(7/2823) + (5/2823)x\log_2(5/2823) + (170/2823)x\log_2(170/2823) + (29/2823)x\log_2(29/2823) = 0.45.$

The environment may be probably quite stressful with few ecological microhabitats and only few mycorrhizal species adapted to the disturbed soil sampling sites. Park *et al*., (2016) have shown that activities such as mining considerably reduce the diversity of AMF.

4.7 Distribution of isolated endomycorrhiza species within the studied sites: Table 3 presents the distribution and the relative abundance of the AMF specie in the studied sites. Endomycorrhiza species did not have a uniform distribution in sampling sites. Species of the genus *Glomus* in particular, were more representative compared to other genera. *Glomus constrictum* was the most abundant and ubiquitous species, while *Acaulospora kentinensis* was the less frequent species, since it was encountered only in the Mayo Danay department soil samples. These observations are consistent with others findings by Voko *et al*. (2013) in Ivory coast, who reported the abundance and diversity of cassava-associated AMF in a locality where the genus *Glomus* was the most representative, while those belonging to the genera *Gigaspora*, *Scutellospora* and *Pacispor*a were found in minority. Similar results were pointed out by Moreira *et al*., (2015), who reported the family of Glomeraceae to be dominant including the genus *Glomus* in the rhizosphere of *Jatropha curcas*. The predominance of the genus *Glomus* in all these researches may be related to their ability to establish a hyphal network and sporulate more rapidly. *Glomus* as dominant genera in soils was reported to be also attributed to the ability of their spore to grow in a widely range of environment, including optimum pH between 5.5 to 8 (Tuheteru, 2003). The dominance of *Glomus* sp. in the polluted soil was reported to be due to its higher metal tolerance capacity as reported earlier by previous researchers (Chen *et al*., 2007; Zaefarian *et al*., 2010).

Table 3. Relative abundance of endomycorrhiza within the *Zea mays* rhizospheres of different departments

	Mayo Tshanaga	Diamare	Mayo Danay	Bénoue	Mayo Rey	Mayo Louti	Vina	Faro-Déo	Mbere
G. constrictum	***	***	***	***	***	***	***	***	***
G. maculosum	+	+	+	+	+	+	+	+	+
G. manihostis	-	+	-	-	-	-	-	+	+
A. kentinensis	-	-	+	-	-	-	-	-	-
R. intraradices	+++	+++	+	+	-	+	+	+	+
D. epigae	+	+	-	+	-	+	+	+	-

-: absent; +: weakly abundant (120); ++: Averagely abundant (21-40); +++: abundant (41-100); ***: highly abundant (> 100).

4.8 Correlation between studied parameters of *Zea mays* (L.): Table 4 reveals significant negative correlations between sand and clay ($r = -9232$, $P < 0.0005$), species richness and sand content ($r = -851$, $p < 0.0012$). However, positive and significant correlations were observed between AMF species richness and clay content ($r = 0.7025$, p

< 0.034) on one hand, the mycorrhization frequency and mycorrhizal intensity (r = 0.7161, p < 0.0301) on the other. These results indicate that the specific richness of the AMF spores increases with the clay content and support those of Diouf *et al.* (2013), who have shown that clay is a substrate for the multiplication of *Glomus intraradices*, *G. mosseae* and *G. verruculosum* in *Zea mays* in the plant rhizospheres. However, the decrease in specific richness with the sand content is an indication that these soils are subjected to agricultural practices that negatively affect AMF communities in soils.

Table 4. Correlation between assessed parameters

	Phosphorus	**pH**	**clay**	**Sand**	**Frequency**	**Intensity**	**Richness**
Phosphorus							
pH	r = 0.161						
	p = 0.679**ns**						
Clay	r = 0.350	-0.344					
	p = 0.355 **ns**	0..364**ns**					
Sand	r = -0.246	0,082	-0.923				
	p = 0.523 **ns**	0.832**ns**	0.0004**				
Frequency	r = -0.281	-0.062	-0.490	0.557			
	p = 0.463 **ns**	0.873**ns**	0.180**ns**	0.118**ns**			
Intensity	r = 0.073	0,435	-0.328	0.333	0.711		
	p = 0.850 **ns**	0.241**ns**	0.388**ns**	0.380**ns**	0.030**		
Richness	r = -0.003	0.059	0.702	-0.895	-0.567	-0.452	
	p = 0.993**ns**	0.879**ns**	0.034**	0.001**	0.110**ns**	0.221	

** indicates significant correlations. ns indicates non-significant correlations ; n=9 : number of samples

5 CONCLUSION

In this study, maize [*Zea mays* (L.)] was found to be dependent on endomycorrhizal symbiosis in Northern Cameroon. Six AMF species were involved in this symbiosis in the Adamawa, Far-North and North regions of Cameroon, of which are: *Glomus constrictum*, *Glomus maculosum*, *Glomus manihotis*, *Acaulospora kentinensis*, *Rhizophagus intraradices*, *Diversispora epigae*. The strain *Gomus constrictum* was dominant, while *Acaulospora kentinenensis* was the less frequently encountered specimen. The identification of these multi-native endomycorrhizal spores structures in soils is a potential opportunity for production of endomycorrhizal inoculants to boost maize yields in this part of the country. Since AMF are not specific to a single host plant, these inoculants could be inoculated to other crop plants.

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