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Changes in the Structure of Arbuscular Mycorrhizal Fungi Communities and Identification of Persistent and Indicator Species in Soils of Different Cassava (*Manihot Esculanta*, Crantz) Growing Areas In Côte d'Ivoire

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Abstract

Cassava's adaptation to diverse environments is thought to be linked to its ability to take better advantage of the activity of soil microorganisms, particularly the symbiosis of arbuscular mycorrhizal fungi (AMF) on which its survival depends. However, the dynamism of AMFs and the factors involved in the case of cassava monocultures practiced over long periods of time on the same soil have been little studied. In this work, the objective was to identify AMFs species frequently found in cassava rhizosphere in three agro-ecological zones of Côte d'Ivoire. Thus, the relative abundance of AMF species in relation to the ecological factors of cassava cultivation in each zone was established. The physicochemical conditions of the soils in the eastern zone (Abengourou) were favorable to cassava cultivation while in the southern zone (Azaguié), these properties were not suitable for cassava cultivation. Soils in the centre zone (Yamoussoukro) had intermediate properties. Three species of AMFs (Acaulospora colombiana, Acaulospora scrobiculata and Rhizophagus intraradices) were ubiquitous and predominant in the cassava rhizosphere whatever the zone. Some species were rare (Gigaspora margarita; Racocetra spp., Rhizophagus. Manhiotis, Paraglomus sp.). Agro-ecological zone, crop rotation and pH have an influence on the relative abundance of AMFs in the soil.

Keywords: *Arbuscular mycorrhizal fungi, predominant species, cassava, agro-ecological area,*

INTRODUCTION

Cassava (*Manihot esculenta*, Crantz) is a rustic Euphorbiaceae that adapts many types of ecosystems. In Ivory Coast, cassava is produced in all cultivation areas is becoming the second food crop. The adaptation of cassava in various environments is linked to its ability to make better use of ecological balances and activity of soil microorganisms including arbuscular mycorrhizal fungi (AMF) symbiosis which its survival depends (Sieverding, 1989; Ceballos *et al*., 2013). The arbuscular mycorrhizal symbiosis involves more than 85 % of terrestrial plants, the great majority of cultivated plants. This association between plants and AMF dates back to 400 million years ~~ago~~ when the continents were deserted. In this complementary both groups of organisms have co-evolved. Today in all ecosystems, the role of CMA is reflected by faciliting access to more plant soil mineral nutrient, protection of plants against attacks of soil microorganisms (Smith and Read, 1997), providing good enhanced drought resistance (Auge *et al*., 1994), but also improving soil structure (Rillig *et al*., 2002; Gadkar and Rillig, 2006). AMFs are important for major plant physiology, plant health, nutrient cycling, and soil aggregation, particularly for low input, sustainable agriculture systems (Rillig *et al*., 2016).

Furthermore, mycorrhizal associations are strongly involved in the dynamics of plant successions without any real specificity between fungi and their plant hosts (Hartnett and Wilson, 2002). Thus, on degraded soil, the first plant species that appear are those that would have a greater mycotrophy. In other words, fungal biodiversity would have more impact on the type of plant population than vegetation on the fungal diversity of soils (Hartnett and Wilson 1999; Garcıa de Leon *et al*., 2016). In reality, in the environment, the population and the activity of microorganisms such as AMF resulting from a global ecological balance including the ecological system considered, the physicochemical properties of the soil, the biological activity of the soil and the type of land use (Yang *et al*., 2010 ; Stürmer and Siqueira 2011). The role of AMF in functioning stability and the evolution of ecosystems has been repeatedly reported (Simard and Durall 2004). However, in modified or disturbed events, particularly in the case of monocultures practiced for long periods on the same land, There are few studies focusing on the factors having an impact on the life cycle of AMF in tropical areas.

In this work, the aim is to highlight the AMF species frequently occurred with cassava cultivation across the different agro-ecological areas. The following assumptions will be considered: (1) Some AMF species are predominant in the rhizosphere of cassava. (2) These predominant species would play a major role in the adaptation of cassava to the soils of these different agroecological zones. (3) Changes in AMF communities is influenced by factors such as the physicochemical properties of soils or cultural succession.

MATERIAL AND METHODS

Exploratory survey

Three important cassava production sites in Côte d'Ivoire (Abengourou, Yamoussoukro and Azaguié) were chosen for this study. Abengourou is located in the east of Côte d'Ivoire with a subequatorial climate, constituted by dense rainforest. Avarage annual rainfall is 1500 mm. Azaguié is located in the southeast forest of Côte d'Ivoire. The climate of Azaguié is ~~a~~ sunny tropical humid and the average annual rainfall is 1700 mm. Yamoussoukro is located in the center of Côte d'Ivoire in the savannah-forest transition with average rainfall ranges from 1100 mm to 1600 mm. The cassava fields selected for the study were chosen following an exploratory survey on the typology (area, chemical treatment, cropping system and previous crops) of fields in these large cassava production sites in Côte d'Ivoire. This survey made it possible to determine the main cassava cultivation habits in each zone.

Soils ampling

Soil samples were collected from cassava fields in December, during the harvesting period from four fields of each sites (Figure 1). At each field, three samples were collected according to the regimen

proposed by Huang and Cares (2004). A total of 36 samples were collected for the study i.e. 12 samples for each agroecologigical area. The soils were brought up to the laboratory. Each replicate was air-dried, filtered and divided into three sub-sets from which soil parameters were determinated, AMF spores and propagation, spore production in trap cultures were isolated and identified.

Soil physico-chemical analyses

Air-dried soils were used to determine soil chemical and physical characteristics. Soil pH was determined according to Pansu and Gautheyrou (2006). Organic carbon was assessed using the method of Walkley and Black (1934) and soil N by the Kjeldahl method (MacDonald, 1977). Soil cationic exchange capacity (CEC) and total P were determined respectively using the method by Duchaufour (1977), Pansu and Gautheyrou (2006). Soil available phosphorus was determined according Olsen (1952) and soil textural classes using French standards of soil classification (Aubert, 1962).

Trapping culture

For each sampling point, three culture pots (small 2 L plastic bucket) were established. The inocula consisted of 100 g of soil sampled at each point, mixed with 1000 g of autoclaved compost. Two to five day old cowpea (Vigna unguiculata) seedlings were added per pot. A total of 15 pots were set up, including three non-mycorrhized control pots containing 1000 g of compost substrate previously sterilized in an oven at 120°C for 2 h 30 min. 75 days later, 50 g of soil was collected from each pot for AMF spore extraction.

Arbuscular mycorrhizal fungal (AMF) spore isolation

AMF were isolated by spore extraction from soil samples or trap culture. Spores were extracted by wet-sieving and decanting (Gerdemann and Nicolson 1963) using sieve with different sizes (45, 90, 125 and 500 µm) and the modified sucrose density gradient centrifugation method (Walker *et al*., 1982).

Arbuscularmycorrhizalfungal (AMF) spore identification

For species identification, healthy spores were mounted on glass microscope slides and stained with polyvinyl alcohol-lacto-glycerol (1vol/1vol) (PVLG) mixed with and without Melzer's reagent (Morton *et al*., 1993; Brundrett *et al*., 1994). Spores were cracked open to allow spore substructure characteristics under an optic microscope (EUROMEX Holland CSL/CKL) at a magnification of x 400. AMF spore morphotyping was based on Oehl *et al*., (2011) morphological description, Morton *et al*., (1993) current species description and their classification has been done according to the revision of Glomeromycota genera proposed by Redecker *et al*., (2013).

Species relatives abundance

AMF spores were counted using binocular magnifying glass (EUROMEX Holland STO 11738).
Spore density was expressed in terms of unit mass of dry soil.

Data analyses

AMF spore abundance was recorded as spore number.g^{-1} soil. The species richness was recorded as the species number. Occurrence (%) was defined as the number of samples in which a taxon (species or genus) was observed on the total number of samples (= 36). All statistical analyses were realized using STATISTICA program (version 7.1, 2005). For the evaluation of differences between sites, non-parametric tests, ANOVA of Kruskal-Wallis and *U* Mann-Whitney test ($p < 0.05$) were used. Natural clusters in the collected data, were determined through a hierarchical cluster analysis (HCA) based on Euclidian distance measure and Ward aggregation method were performed.

RESULTS

Cassava fields typology

The main characteristics of cassava fields are shown in Table 1. In Abengourou area, fields (Ab_1, Ab_2, Ab_3 and Ab_4) are cassava monocultures of 10 to 13 months old. Cultural technique is a rotation in which yam is at the start of rotation just after 4 to 6 years fallow and cassava intervenes at the end of rotation before the beginning of the next fallow. In Azaguié area, crop rotation does not exist, short fallows of 2 to 4 years precede a succession of cassava fields. Cassava fields (Az_1,Az_2,Az_3 and Az_4) are 10 to 13 months monocultures. In Yamoussoukro area, for two fields (Ya_2 and Ya_3), the cultural technique is a rotation with yam at beginning of rotation and cassava monoculture at the end before starting of next fallow of 4 to 5 years. For the two other fields (Ya_1 and Ya_4), cassava occurs just after the 5 year fallow. Yamoussoukro cassava fields are monocultures of 10 to 12 months old.

Chemical and physical fertility of soils in cassava fields

Physico-chemical characteristics of the cassava field soils are shown in Table 2. In Abengourou agro-ecological zone, pH of cassava field soils is acidic (5.50 to 6.41). The soil texture is either silty or silty sandy with a large proportion of fine silt. The cation exchange capacity (CEC) is high for all soils and the proportions of nitrogen (N) and organic matter (OM) are also high. The C/N ratios for this area reflect good decomposition of organic matter. However, except for soils in the field Ab_2, the assimilable phosphorus (Pass) contents are low in most of the soils in this area.

Soils of Azaguié agroecological zone are all silty-sandy texture with a significant proportion of fine sand. Soil pHs are highly acidic at Az 2, Az 3 and Az 4. While the soil pH at Az 1 is acidic. The nitrogen (N) proportions are generally average. The soils in this area have very low cation exchange capacity (CEC) and are poor in organic matter. The C/N ratios reflect poor decomposition of organic matter. And assimilable phosphorus (Pass) contents of all these soils are low.

In Yamoussoukro agro-ecological zone, all soils have a silty-sandy texture with acid pHs at Ya 1, Ya 2 and Ya 3 and a neutral pH at Ya 4. The assimilable phosphorus (Pass) contents of all these soils are low. The proportions of organic matter (OM) vary depending on the cassava field, the soils of Ya 1 and Ya 3 are moderately rich with a normal rate of decomposition of organic matter. While the soils of cassava fields of Ya 2 and Ya 4, have low contents due to poor decomposition of organic matter. Soil of Ya 3 has a high nitrogen (N) content and a good cation exchange capacity (CEC) whereas soils of Ya 1, Ya 2 and Ya 4 have medium nitrogen contents and low cation exchange capacities.

The classification of the soils from the three investigated zones base on the physicochemical properties (Figure 2) shows that the soils of the cassava fields in each zone have their own characteristics wich differ from those of others. The Abengourou zone is distant from Yamoussoukro zone and Azaguié zone by an aggregation distance of about 11.81 while this distance is about 6.78 between Yamoussoukro zone and Azaguié zone.

Diversity and structuring of mycorrhizal fungi communities

Common AMFs spore in cassava field are showed in figure 3. An image of cracked spore under coverslip of *Rhizophagus intraradices* in PVLG + Melzer. This is a 95 µm sized, pale yellow spore with three wall layers (L1, L2 and L3). The spore is carried by a cylindrical subtending hypha, slightly constricted to 16 µm in width (Figure 3A).

An image of a cracked spore under a coverslip of *Acaulospora colombiana* in PVLG + Melzer. It is a 140 µm size, yellow-brown spore with one spore wall (sw) and two germinal walls (gw1 and gw2) of which the gw2 wall stained dark red-purple with Melzer reagent (Figure 3B).

In all three agrecological zones, 17 AMF species have been identified (Figure 4). Their distribution differs from one agrecological zone to another and within the same zone, the relative abundances of the species are not the same. The specific richness in Abengourou is 11, that of Azaguié is 12 and in Yamoussoukro 14 species have been identified. Seven (7) species are present in each of the three zones. These are *Acaulospora scrobiculata, Acaulospora colombiana, Ambispora appendicula, Funneliformis mossae, Glomus clavisporum, Rhizophagus intraradices, Rhizophagus manhiotis.* Among these species, *A. colombiana* is the most abundant species in the three zones, followed by *A. scrobiculata*. The species *F. mossae*; *Glomus sp*. and *R. intraradices* are moderately abundant in the Yamoussokro area. Some species are rare regardless of the area considered, these are *G. clavisporum, Paraglomus* sp., *Racocetra* sp.3, *Septoglomus sp, Sclerocystis sinuosum, Gigaspora margarita, Racocetra* sp.1 and *Racocetra* sp.2. The species *Septoglomus* sp; *Sclerocystis sinuosum* have been identified only in soils of Yamoussoukro zone and the species *Racocetra* sp.1 is found only in soils of the Azaguié zone.

The hierarchical classification by Ward's method of species depending on the cultivation technique (crop rotation with yam at the start of the rotation, crop rotation with fallow before cassava cultivation and the absence of rotation) made it possible to define 2 main classes (Figure 5). The first class is that of frequent species which is subdivided into two subclasses mamely species with a high relative abundance whatever the zone or the cropping system (*A. scrobiculata*; *A. colombiana* and *R. intraradices*) and species with an average relative abundance. The latter group is subdivised into those found in all cropping systems which are *Ambispora appendicula* and *Funneliformis mossae*, and those species found only in crop rotation zone ie *A.cavernata* and *Glomus* sp. The second class is that of rare individuals present in one or two growing regions. This class is also subdivided into two subclasses that are species from sites without crop rotation, *Acaulospora* sp.1, *G. margarita*; *Racocetra* sp.1 and *Racocetra* sp.2 and *R. manhiotis* and species from sites with crop rotation which are *G. clavisporum; Paraglomus* sp*; Septoglomus* sp*; S. sinuosum; Racocetra* sp. 3.

Density of AMF spores base on cassava cultivation conditions

The average AMF spore densities from cassava fields in the three agroecological zones are shown in Figure 6A. Azaguie zone had the lowest average density (12.00 spores / g of soil). The highest average density was obtained with the soils of Yamoussoukro zone (17.28 spores / g of soil). Significant differences are also noted when the density is evaluated in relation to the type of crop rotation (Figure 6B) The soils of fields (Ab_1, Ab_2, Ab_3; Ab_4, Ya_2 and Ya_3) where crop rotation is applied with yam at the start of rotation showed higher AMF spore densities (17.36 spores / g of soil) than those (11.11 spores / g of soil) of soils from fields with no rotation (Az_1, Az_2, Az_3, Az_4, Ya_1 and Ya_4).

The average AMF spore densities of cassava fields were also evaluated base on the chemical properties of the soil. Thus, the densities of AMF sopres (17.72 spores / g of soil) are higher for soils with a pH between 5.50 and 6.50 (Ab_1, Ab_2, Ab_3; Ab_4, Ya_1, Ya_2, Ya_3 and Ya_4), i.e. soils with acidic pH (Figure 6C). However, the densities are lower (12.05 spores/g of soil) for soils with a pH between 4.51 and 5.20 (Az_1, Az_2, Az_3 and Az_4), that is, soils with hygly acidic pH. Regarding the organic matter content (Figure 6D), no significant difference was noted between the average densities of field soils poor in organic matter (Az_1, Az_2, Az_3, Az4, Ya1, Ya_2, Ya_3 and Ya_4) and soils rich in organic matter (Ab_1, Ab_2, Ab_3 and Ab_4). Likewise, no significant difference was observed when the average densities of AMF were evaluated according to the variation in the soil content of assimilable phosphorus (Figure 6E) or potassium (Figure 6F).

Discussion

Understanding the dynamics of AMFs in soils and the factors that can influence these dynamics is necessary for a better use of the services that these micro-organisms provide in agriculture and in the resilience of ecosystems. This study was conducted in three cassava production areas in Côte d'Ivoire. The aim was to determine which AMF species are preferentially associated with cassava cultivation over and above any other physicochemical, ecological, or cultural soil factors. AMFs are known to establish symbiotic relationships with low host specificity (Khasa *et al*., 1990; Garcıa de Leon *et al*., 2016). The results reveal that the chemical conditions of the soils differ from one agro-ecological zone to another, but the soils of the Azaguié zone are more similar to those of the Yamoussoukro zone. The chemical properties of Abengourou soils are different from those of the other two. Indeed, with the exception of the phosphorus deficit, the physico-chemical conditions of Abengourou soils are favourable to agriculture in general. Given the preference of cassava for sandy loam soils (Yaninek and Schulthess, 1993), the mineral mobilisation required for cassava cultivation (Akanza and Yao-Kouamé, 2011) and the ability of cassava to adapt to low phosphorus soils (Tertuliano, 1993), the physicochemical conditions of Abengourou soils are particularly favourable to cassava cultivation. In the Yamoussoukro area, mineral fertility is average. On the other hand, in the Azaguié area, very acidic pH and low mineral fertility were observed. These soils are unfavourable for cassava cultivation. Also, the study revealed that the density of AMF spores in the soil differs according to the agroecological zone. Soils in areas where crop rotation is practised, Yamoussoukro and Abengourou, showed higher AMF spore densities than soils in the Azaguié area where crop rotation is not applied and where the pH is very acidic. Crop rotation would be favourable to the development of AMFs spores (Plenchette *et al*., 2005 ; Gosling *et al*., 2006). Similarly, acidic and neutral pH would be more suitable for AMfs than highly acidic soils. Indeed, the soils of fields Ab_2, AB_3 and Ya_2 with acid pH and those of fields Ab_1, AB_4 and Ya_1, Ya_3 and Ya_1 with neutral pH have higher spore densities than those of soils Az_2, Az_3 and Az_4 with very acid pH. These results are supported by the work of Coughlan *et al* (2000) who demonstrated a positive correlation of pH with the quality and quantity of AMFs in the soil. However, chemical parameters such as the proportion of organic matter, the content of available phosphorus and the content of potassium did not seem to have any influence on the spore density of AMFs. Indeed, for different values of these parameters, no significant difference in spore density was observed. Especially for phosphorus, several studies have shown that there is a link between the concentrations of this mineral in the soil and the relative abundance of AMFs (Gaur *et al*., 2000; Temegne *et al*., 2018; Malonda *et al*., 2019). This link was not proven in this study, as all soils had similar levels of available phosphorus. That is, low levels of available phosphorus characteristic of tropical soils (Sanchez and Jama, 2002).

Although all soils surveyed were 8 to 12 month old cassava (Manihot esculenta, Crantz) fields, the species diversity and distribution was not the same. Within the same agro-ecological area, species are similar and generally have the same distribution on cassava growing soils. However, from one agro-ecological area to another, species diversity and distribution differ. Acaulosporacea and Glomeraceae are the most widespread. Some species of these families such as *Acaulospora colombiana, Acaulospora scrobiculata* and *Rhizophagus intraradices* are ubiquitous and the most abundant in all agro-ecological zones. Other species of these two families such as *Acaulospora cavernata, Funneliformis mossae* and *Sclerocystis sinuosum* are also ubiquitous but with lower relative abundances than the former. On the other hand, Gigasporaceae such as *Gigaspora margarita, Racocetra* spp. are rare and found almost essentially in the cassava fields of the Azaguié area only, where crop rotation is not applied. Also, the species *Paraglomus* sp. of the Paraglomeraceae family was only found in the Yamousoukro area on soils with neutral pH. The predominance of species from the families Acaulosporacea and Glomeraceae has already been reported in studies carried out in tropical croplands (Dodd *et al*., 2000; Jefwa *et al*., 2012). Glomeraceae have been repeatedly shown to be the most abundant in cassava fields (Sieverding, 1989). This predominance of the genera Acaulosporacea and Glomeraceae in the tropics is thought to be due to an adaptation of these AMF genera to tropical conditions, but also to the fact that their development cycle would not be as affected by repeated cropping as that of species of the Gigasporaceae family (Jansa *et al*., 2002; Oehl *et al*., 2003, Tchabi *et al*., 2008). Indeed, species of the families Acaulosporacea and Glomeraceae would spread much more by spores which are forms of resistance of AMFs to harsh conditions while Gigasporaceae would spread more with other types of propagules such as hyphae, extraracinar mycelial fragments (Brito *et al*., 2012). Species of the Acaulosporacea and Glomeraceae families found in cassava field soils would not only be little affected by fluctuations in soil physicochemical parameters but also little influenced by the different cassava cultivation practices in Côte d'Ivoire. All of these results suggest that the presence of AMF communities on cassava-growing soils in each zone is not related to their specificity to cassava or to the different vegetative stands that have prevailed on these soils. These mycorrhizal fungi are thought to have been present since the origin of the soils and the first plants that inhabited them (Smith and read, 1997). Thus, the presence of these AMFs in these different soils precedes the establishment of cassava fields. However, the predominance of species such as *Acaulospora colombiana, Acaulospora scrobiculata* and *Rhizophagus intraradices* would be more related to their capacity to propagate in the local edaphic, ecological and cultural conditions. These predominant species would colonize more easily cassava which is a mycotrophic plant allowing a better adaptation of this plant on different levels of tropical soil fertility.

Conclusion

Cassava is grown in Côte d'Ivoire on soils with different levels of fertility. Three species, *Acaulospora* *colombiana*, *Acaulospora scrobiculata* and *Rhizophagus intraradices* are ubiquitous and predominant in cassava rhizosphere. These species, in contrast to the species of the Gigasporaceae family, are more adapted to local agroecological conditions such as the physicochemical properties of soils or cultural succession. These predominant species participate effectively inthe adaptation of cassava to soils with different ecological characteristics.

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FIGURES

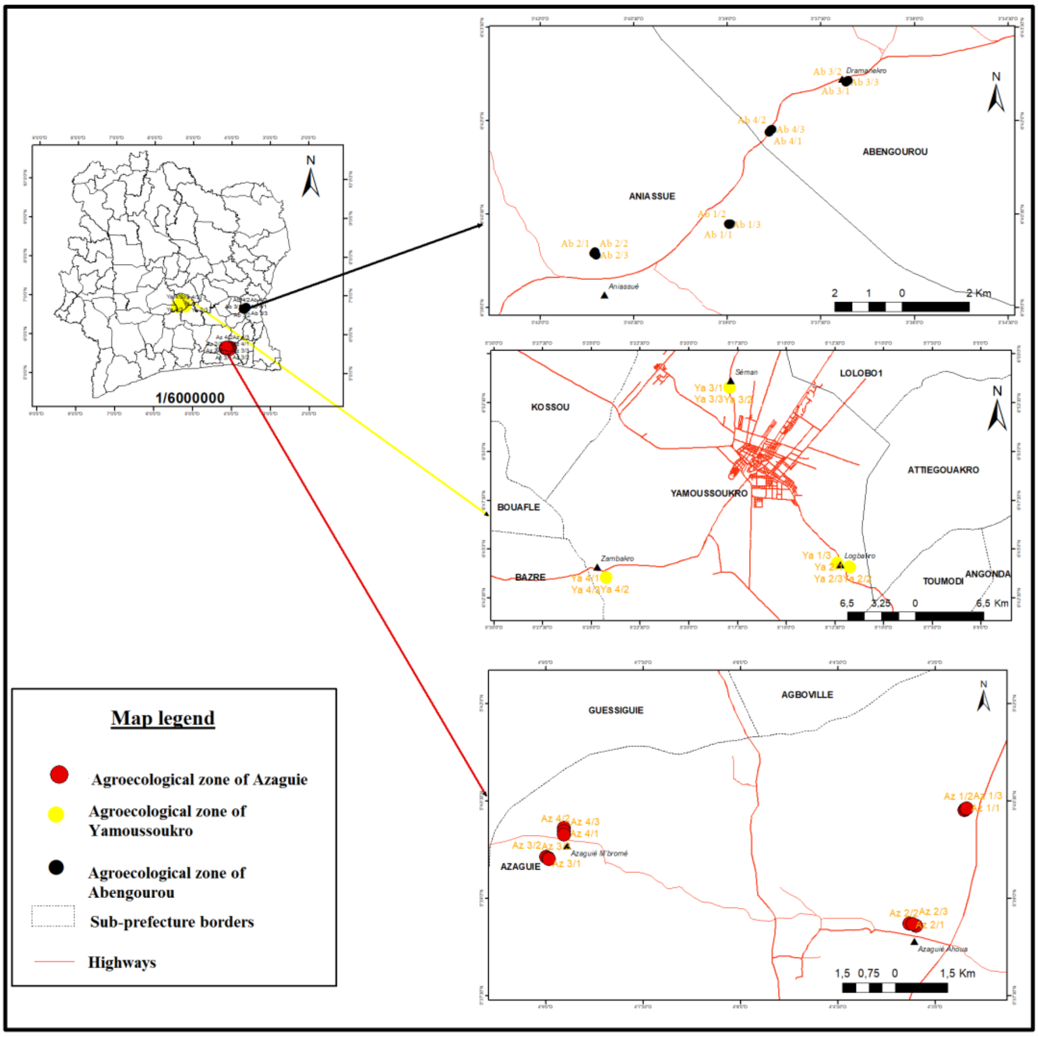

Figure 1. Map of the sampling area

Ab Cassava field in Abengourou area

Az Cassava field in Azaguie area

Ya Cassava field in Yamoussoukro area

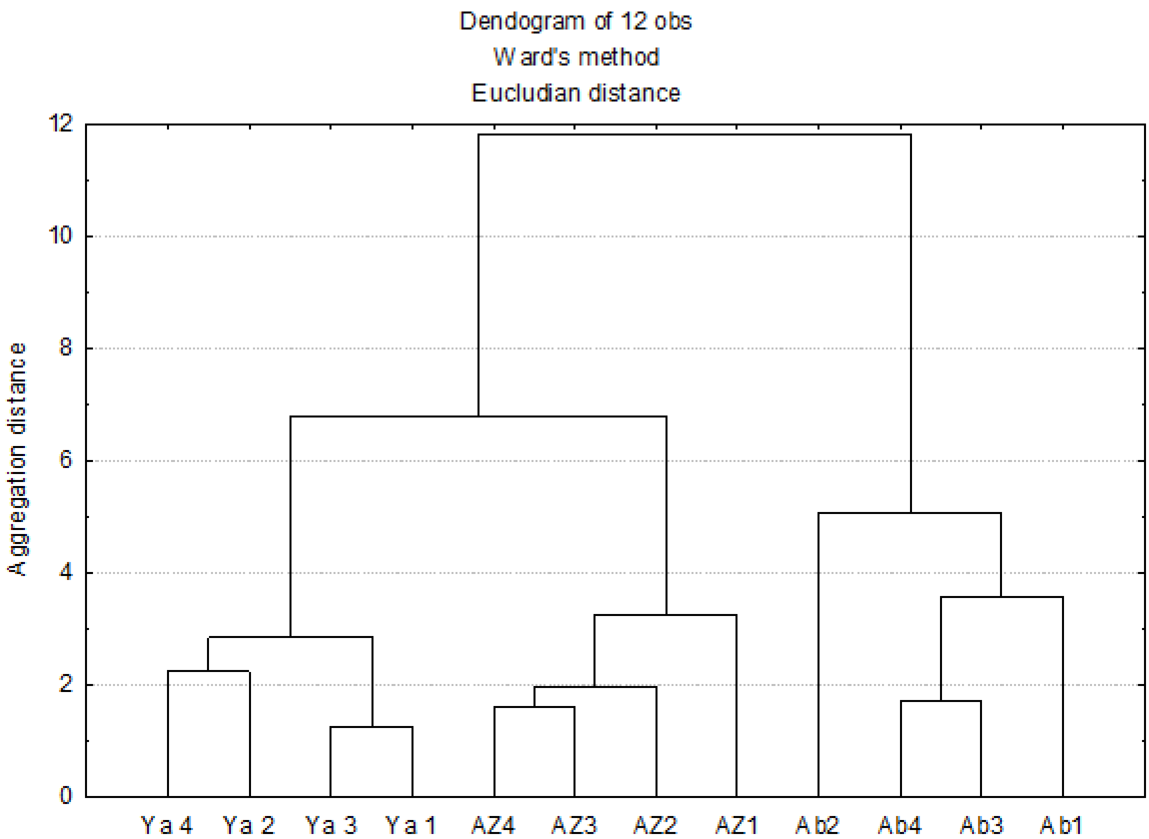

Figure 2. Soils classification base on the physicochemical properties

Ab	Cassava field in Abengourou area
Az	Cassava field in Azaguie area
Ya	Cassava field in Yamoussoukro area

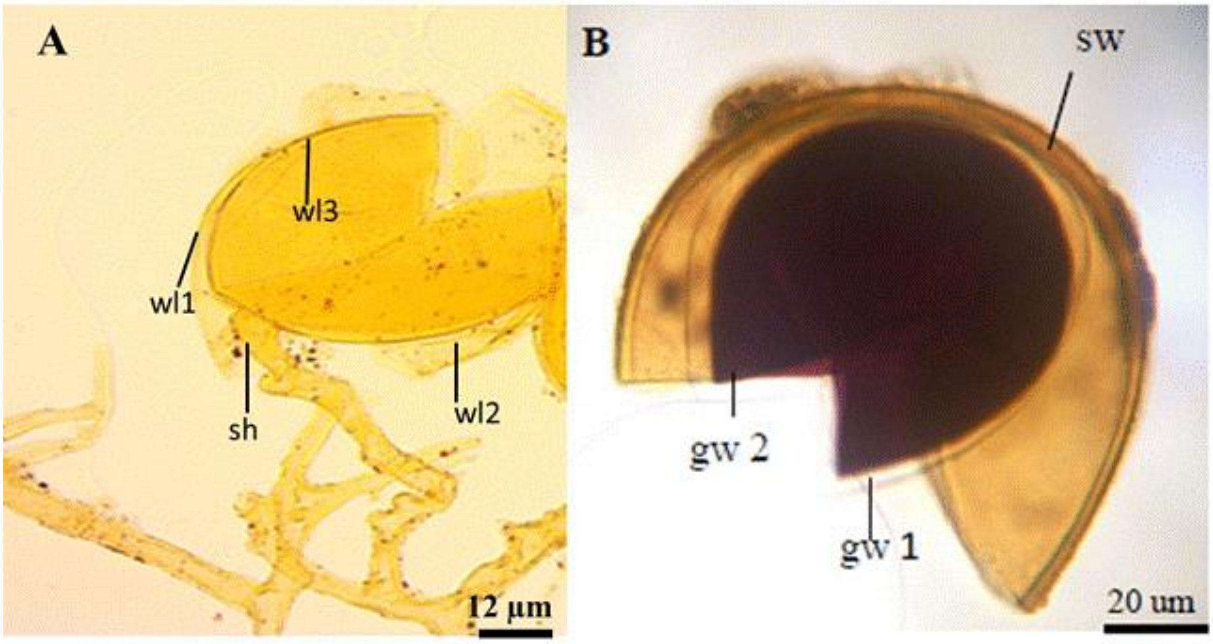

Figure 3. Image of two spores of arbuscular mycorrhizal fungi common in cassava fields

A : *Rhizophagus intraradices* in PVLG + Melzer; B: *Acaulospora colombiana* in PVLG + Melzer

sh: Subtending hypha; wl : Wall layer; sw: Spore wall; gw: Germinal wall

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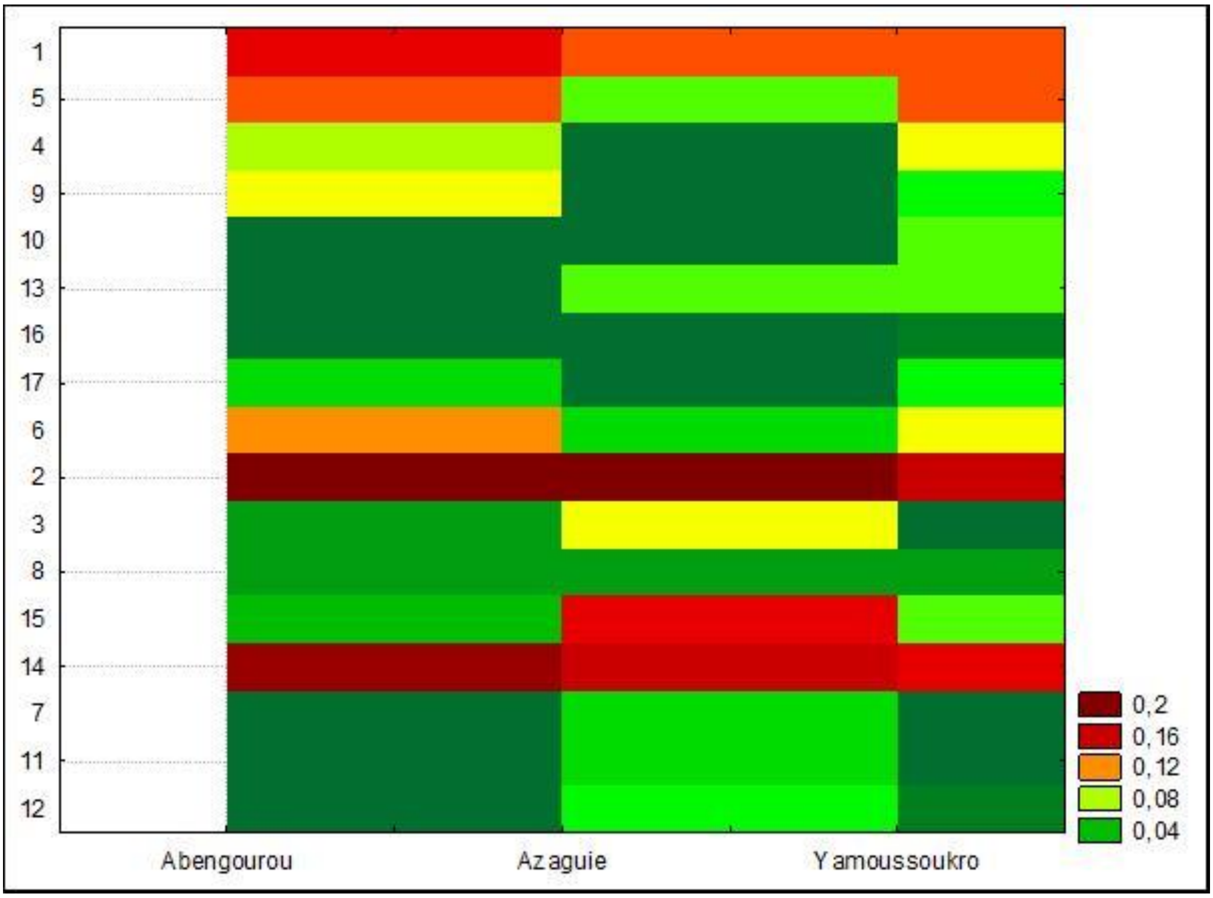

Figure 4. Joint classification of AMF species according to their relative abundance in the agro-ecological zones

0,2 **Highly abundant**
0,16 **Abundant**
0,12 **Moderately abundant**
0,08 **Rare**
0,04 **Extremely rare**

1 *Acaulospora scrobiculata*; 2 *Acaulospora colombiana*; 3 *Acaulospora sp.*1; 4 *Acaulospora cavernata*; 5 *Ambispora appendicular*; 6 *Funneliformis mossae*; 7 *Gigaspora margarita*; 8 *Glomus clavisporum*; 9 *Glomus* sp.; 10 *Paraglomus* sp.; 11 *Racocetra* sp.1; 12 *Racocetra* sp.2: 13 *Racocetra* sp.3; 14 *Rhizophagus intraradices*; 15 *Rhizophagus manhiotis*; 16 *Septoglomus* sp.; 17 *Sclerocystis*

October 31, 2021

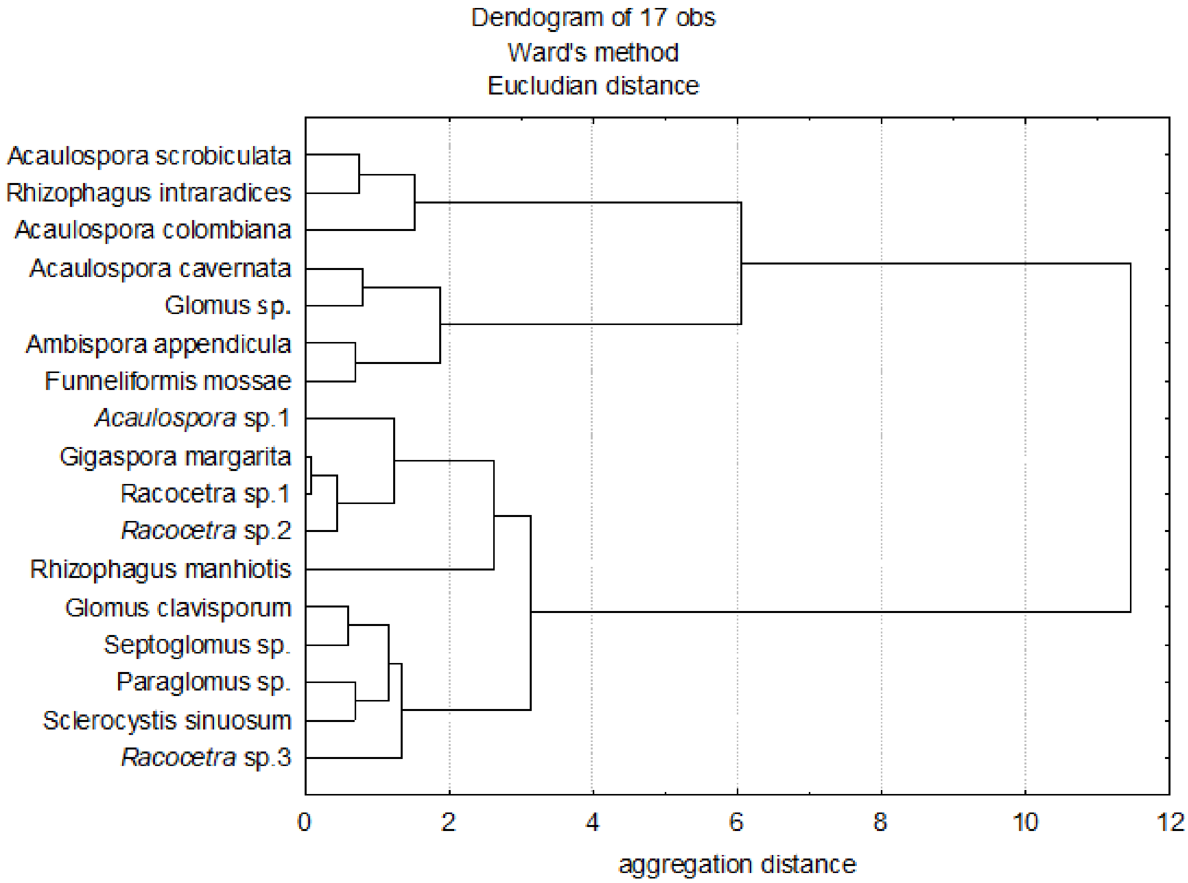

Figure 5. Classification of species according to their relative abundan

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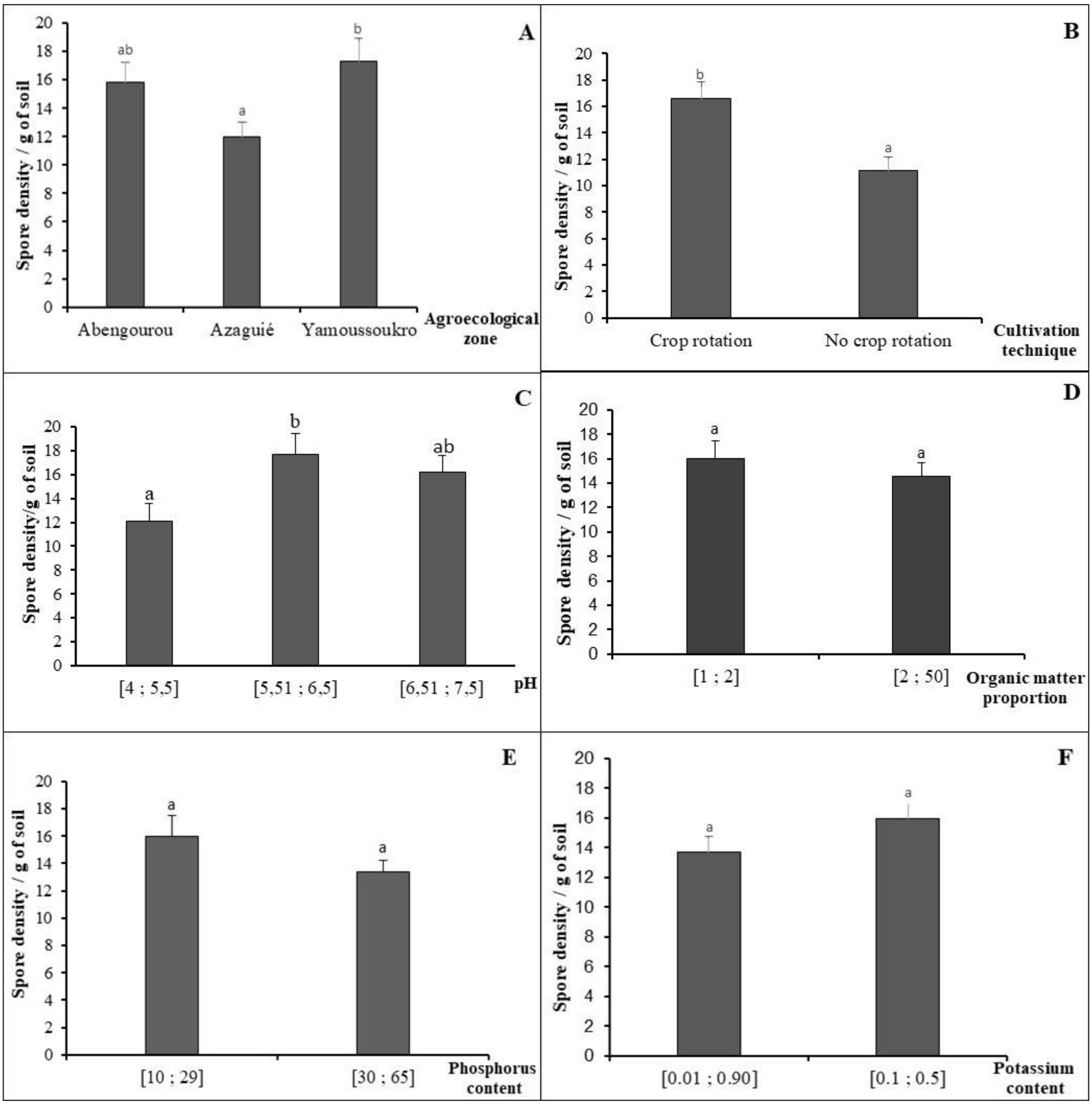

Figure 6. Arbuscular mycorrhizal fungi spore density in cassava field soils according to agroecological characteristics

A Densities of AMF spores in cassava fields in the three agroecological zones
B Density of AMF spores base one type of cultivation
C Density of AMF spores according to pH of soils
D Density of AMF spores according to proportion of soil in organic matter (OM)
E Density of AMF spores according to assimilable phosphorus content

F Density of AMF spores according to assimilable potassium content

TABLES

Table 1: Characteristics of cassava fields in agro-ecological zones

Cultivation areas	Fields	Age of field (months)	Chemical treatment	Culture system	precedent cultures
Abengourou	Ab1	10	no	Single culture	Fallow (5 years)-Yam
	Ab2	10	no	Single culture	Fallow (4 years)-Yam
	Ab3	12	no	single culture	Fallow (6 years)-Yam
	Ab4	13	no	single culture	Fallow (4 years)-Yam
Azaguie	Az1	12	no	Single culture	Fallow (2 years)-Cassava
	Az2	12	no	Single culture	Fallow (2 years)-Cassava
	Az3	13	no	single culture	Fallow (4 years)-Cassava
	Az4	10	no	single culture	Fallow (4 years)-Cassava
Yamoussoukro	Ya1	12	no	Single culture	Fallow (5 years)-Cassava
	Ya2	11	no	Single culture	Fallow (5 years)-Yam
	Ya3	10	no	single culture	Fallow (4 years)-Yam
	Ya4	11	no	single culture	Fallow (5 years)-Cassava

Ab Cassava field in Abengourou area

Az Cassava field in Azaguie area

Ya Cassava field in Yamoussoukro area

Table 2. Physico-chemical characteristics of the cassava field soils

Fields	pH	O.M %	N %	C/N	P. (ppm)	K^+ (cmol.kg^{-1})	CEC (cmol.kg^{-1})	Texture
Ab1	6,41[cd]	33,57[c]	0,28[a]	9,49 [ab]	22,62 [a]	0,11 [ab]	20,67 [de]	Silty-sandy
Ab2	5,50[abcd]	19,13[bc]	0,30[a]	10,60 [b]	55,95 [b]	0,20 [ab]	23,67[e]	Silty-sandy
Ab3	5,87[bcd]	26,67[c]	0,25[a]	9,06 [ab]	23,57 [a]	0,16 [ab]	17,92 [cde]	Silty
Ab4	6,27[bcd]	29,42[c]	0,32[a]	8,27 [a]	29,76 [ab]	0,23 [ab]	18,60[cde]	Silty
AZ1	5,19[abc]	1,93[a]	0,14[a]	9,66 [a]	29,76 [ab]	0,04[a]	5,84[a]	Silty-sandy
AZ2	5,00[ab]	1,70 [a]	0,15[ab]	6,82 [a]	30,71 [ab]	0,04[a]	07,95 [ab]	Silty-sandy
AZ3	4,97[ab]	2,10 [a]	0,18[ab]	6,72 [a]	19,00 [a]	0,044[a]	17,1[cde]	Silty-sandy
AZ4	4,51[a]	2,38 [a]	0,22[b]	6,24[a]	25,00 [a]	0,11 [ab]	12,21[abcd]	Silty-sandy
Ya 1	6,28[bcd]	2,49 [a]	0,15[ab]	9,67 [a]	17,86 [a]	0,16 [ab]	9,48[abc]	Silty-sandy
Ya 2	5,77[abcd]	1,60 [a]	0,11[a]	8,55 [a]	20,95 [a]	0,28 [b]	07,52 [ab]	Silty-sandy
Ya 3	6,39[cd]	2,74 [ab]	0,17[b]	9,31 [a]	19,52 [a]	0,10 [ab]	14,75[abcde]	Silty-sandy
Ya 4	6,55[d]	1,61 [a]	0,14[ab]	7,08 [a]	21,90 [a]	0,16 [ab]	07,04 [a]	Silty-sandy

Ab Cassava field in Abengourou area

Az Cassava field in Azaguie area

Ya Cassava field in Yamoussoukro area