ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-0912 (Print)
ISSN: 2521-0513 (Online)
CODEN: JCOLBF

Journal CleanWAS (JCleanWAS)

DOI: http://doi.org/10.26480/jcleanwas.01.2022.27.32

CrossMark

RESEARCH ARTICLE

POPULATION DENSITY OF ARBUSCULAR MYCORRHIZAL FUNGI AND PHYSICO-CHEMICAL PROPERTIES OF SOILS AS AFFECTED BY CROPPING SYSTEMS

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ARTICLE DETAILS

Article History:

Received 25 April 2022
Accepted 30 May 2022
Available online 02 June 2022

ABSTRACT

Cropping pattern exerts significant impact on the population density of the arbuscular mycorrhizal fungi (AMF) and on soil properties. The study examined the population of indigenous AMF communities as well as status of soil properties under different cropping systems in Aluu, Rivers state, Nigeria. Two farm sites of mono cropping and mixed cropping systems and a fallow land (which served as control) were sampled at 0 - 20 cm depth of soil. Soil samples were analyzed in the laboratory for their physical and chemical properties as well as for the estimation of AMF spore density and resulting data were analyzed statistically. Result shows that, soils of the mono cropping and mixed cropping systems are moderately acidic with mean pH values of 5.80 and 5.74, respectively, while the fallow land exhibits a strongly acid soil reaction (pH = 5.29). Concentrations of organic C (9.25 g kg^{-1}), total N (0.97 g kg^{-1}), exchangeable Ca^{2+} (3.63 cmol kg^{-1}), available P (13.31 mg kg^{-1}) and C:N ratio (7.87) as recorded in the mixed cropping system, were generally higher than the corresponding results in the fallow and mono cropping systems. Spore population of the AMF varied significantly ($P < 0.05$) across the cropping systems and was highest in the mixed cropping (157 spores 100 g^{-1} soil) followed by the fallow (144 spores 100 g^{-1} soil) while the mono cropping (123 spores 100 g^{-1} soil) had the lowest spore density. Significant negative ($P < 0.05$) correlations occurred between AMF spore population and soil pH in both the fallow ($r = 0.689^*$) and mixed cropping (-0.670^*) systems whereas correlation with C:N ratio was positively significant ($P < 0.01$) across the cropping systems. Adoption of mixed cropping rather than mono cropping practices should be encouraged in the studied area in order to enjoy maximum benefits of mycorrhizal symbiosis.

KEYWORDS

Arbuscular Mycorrhizal Fungi, Cropping Systems, Soil Properties, Spores

1. INTRODUCTION

Soil is a vital living ecosystem exhibiting some physical, chemical and biological characteristics which interact to determine its ability to sustain crop production. Several agricultural practices including cropping systems, affect the capacity of the soil to perform its primary ecosystem functions of food production. Cropping systems greatly vary, from simple monocultures to complex intercropping systems throughout the world (Plenchette et al., 2005). In Nigeria, particularly in the southern region where soils present low fertility, intercropping, the system of growing more than one crop type on the same farmland, has been in wide practice relative to mono cropping system, where only one type of crop is planted. Intercropping enables farmers to exploit nature's principle of diversity on their farms. It was reported that Eucalyptus intercropped with leguminous trees triggered nutrient cycling in soil, increased plant biomass production and improved soil fertility (Bini et al., 2013; Paula et al., 2015; Bachega et al., 2016). Intercropping increased crop yields significantly in a maize/faba bean system with 21–23 and 6.5–11.8% yield boost over the equivalent mono cropping system (Li et al., 2011; Xia et al., 2013). The mono cropping system, on the other hand, negatively affected crop performance significantly, causing irreversible damage to the soil ecological system (Watts, 2018). Mono cropping lacks diversity and can limit the healthy functions which nature can bring to the soil (Watts, 2018).

Soil properties serve as important indices of soil quality and helps to understand the suitability of soils for agricultural production (Trivedi et al., 2016; Iqbal et al., 2014). Cropping systems can affect a number of soil properties and ultimately determine soil productivity. Adoption of suitable cropping system can be beneficial in improving important soil properties such as organic matter and total nitrogen contents which are useful to both plant and microbial communities (Sharma et al., 2012; Yesilonis et al., 2016). Relative to cultivated land use systems, a group of researchers reported a comparable higher total nitrogen, soil organic carbon and other soil nutrients under the fallow system (Sharma et al., 2012; Trivedi et al., 2016). However, Jokela noted that mixed cropping system involving grass-legume pasture, improved soil properties and overall soil quality relative to monoculture system (Jokela, 2011). In general, many past studies opined that intercropping could help maintain soil quality as well as reduce crop failures (Dallal, 1974; Sharaiha et al., 2004; Nursima, 2009).

Interaction between plant roots and soil microorganisms such as the arbuscular mycorrhizal fungi can offer numerous benefits to agricultural fields. Arbuscular mycorrhizal fungi (AMF) are obligate symbionts, belonging to the phylum *Glomeromycota*, which establish mutualistic association with about 85% of land plants (Schubler et al., 2001; Wang and Qui, 2006). The AMF play a vital role in many ecological processes. They

Quick Response Code	Access this article online	
	Website: www.jcleanwas.com	**DOI:** 10.26480/jcleanwas.01.2022.27.32

Cite the Article: Nzube Thaddeus Egboka, Leonard Chimaobi Agim, Michael Akaninyene Okon, Nnaemeka Henry Okoli, Akaninyene Isaiah Afangide, Philomena Nkem Okonjo (2022). Population Density of Arbuscular Mycorrhizal Fungi and Physico-Chemical Properties ofSoils as Affected by Cropping Systems. *Journal CleanWas, 6(1): 27-32.*

influence organic matter decomposition and cycling of mineral nutrients (especially phosphorus), offer protection to plants against environmental stresses as well as improve plant health and nutrition. Spores of the AMF essentially represent an important index of the fungal populations since they constitute a major component of AMF propagules (Egboka et al., 2022). Thus, enumeration of the spores has been a very useful approach in evaluating the population density of the AMF. Spores are ubiquitous in agricultural soils, and it is supposed that spores and fungi in root fragments are the main sources of mycorrhizal infection in agricultural soils, especially at the inception of the growing season (Abbott and Gazey, 1994). A range of factors including agricultural practices, are known to influence the population density of the AMF in soil (Liu et al., 2012; Oehl et al., 2010).

Cropping systems that involve highly mycorrhizal dependent plants can encourage mycorrhizal infection in soil and consequently, increase AMF population. Therefore, establishment of mycorrhizal association in agricultural fields is largely a function of cropping systems, and especially, the cropping pattern of plants exhibiting mycorrhizal dependencies. The density and composition of AMF communities in the soil can be influenced by intensive agricultural practices such as continuous cropping, and generally, the population of AMF in soil is expected to be lower under mono cropping than the corresponding mixed cropping systems (Zubek et al., 2013).

Research in mycorrhizal technology has received considerable attention since the realization of the potentials of the soil fungi-plant interactions in agricultural field. The recent advocacy of precision agriculture in a bid to achieving increased food security, however, has encouraged experts in the field to tailor research in mycorrhizal technology towards specific agricultural practices, especially those commonly practiced within a given locality. Although the effects of agricultural practices such as land use systems, tillage operation and fertilizer application on the population density of indigenous AMF communities in soils are already well documented, only a little information exist on how cropping sequence affects AMF populations (Picone, 2000; Muthukumar and Udaiyan, 2002; Soka and Ritchie, 2015; Egboka et al., 2022). An understanding of the impacts of different cropping systems on soil properties, is also crucial for designing sustainable soil management practices (Tesfahunegn and Gebru, 2020). The present study thus, assessed the population density of the AMF and status of soil properties under mono cropping and mixed cropping systems in Aluu community, Rivers State, Nigeria, being common cropping systems practiced in the southern region of the country.

2. Materials and Methods

2.1 Study Area

The study was carried out in Aluu community of Ikwerre Local Government Area, Rivers state, Nigeria. The area lies between latitudes $4^0$46'1" N and longitudes $6^0$56'58" E with elevation of 73 m above the sea level. The location belongs to the humid tropical belt of the Niger-Delta area of Nigeria, with marked wet and dry seasons. The wet or rainy seasons start and end in April and November, respectively, while the dry season starts in December and ends in March, giving rise to typical bimodal rain distribution pattern (Ayaode, 2004). The climate of the area is profoundly influenced by its proximity to the Atlantic Oceania and the Orashi River, while the geology is coastal plain sands. The mean annual rainfall is above 2200 mm and rainfall amounts are lower between November and February. Relative humidity values ranged from 86.5 to 92.0%. The vegetation in the study area comprised farmlands (majorly cassava farms) and forest re-growth or fallows of approximately 3 years. Oil palm (*Elaeis guineensis*) is the main growing canopy tree species in the area.

2.2 Collection of Soil Samples and Laboratory Analysis

Soil samples were taken with a soil auger from two large farms under mono cropping and mixed cropping systems, and from an adjacent fallow land (which served as control). Four (4) core soil samples were randomly collected at 0 – 20 cm depth from each of the cropping systems and the fallow land. Hence, a total of 12 soil samples were collected for the study. Soil samples were air dried at room temperature in preparation for laboratory analysis. Each replicate sample was divided into two subsets: to determine the status of soil properties as well as estimate the population density of AMF in the soils.

Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Soil pH was determined in a 1:2.5 soil to liquid suspension using the glass electrode pH meter, soil organic carbon was estimated by the walkley and black wet oxidation method and total nitrogen by the micro kjedahl method of Bremner as modified (Hendershot et al., 1993; Udo et al., 2009). Available phosphorus was determined calorimetrically by Melich III method as described, while exchangeable cations was extracted in Melich III solution and determined instrumentally using the Atomic Absorption Spectrophotometer (AAS) (Udo et al., 2009; Spark, 1996).

2.3 Extraction and Separation of Mycorrhizal Spores from Soil Particles

Spores of the AMF were extracted from the soil samples according to the wet sieving and decanting method (Gerdemann and Nicolson, 1963). A 100 g aliquot of each replicate soil sample was suspended in 1 litre of water by gentle stirring. Heavier particles were allowed to settle for a few seconds and the liquid decanted was passed through a 500 µm sieve to remove large particles of organic matter and allow the spores pass through. The suspension was next passed through a 212 and 106 µm sieves and then through a 53 µm sieve. Spores and small number of debris that remains on the 63 and 106 µm sieves were transferred into a centrifuge tube containing water and centrifuged at 1800 rpm for 5 minutes. The upper solution was discarded, and 40% sucrose solution was added to the debris at the bottom. The mixture was again centrifuged for 2 minutes at 1800 rpm and the upper solution was separated for examination under the microscope.

2.4 AMF Spore Count

Spore population of AMF was determined by direct counting under a compound microscope using the X40 objective. Spore counting was done in a grid-lined Millipore by counting number of spores in the whims separated by the vertical or horizontal gridlines. Both broken and unbroken spores were observed, and the density of AMF spores was reported as number of spores per 100 g of soil.

2.5 Statistical Analyses

Data were analyzed for test of mean differences using one-way analysis of variance (ANOVA). Significant different means were compared using the least significant differences (LSD) at 0.05 alpha level while relationships between AMF spore density and selected soil properties were determined using the Pearson correlation analysis. All statistical analysis was done using the GenStat computer package (4.0 edition).

3. Results and Discussion

3.1 Soil Physico-Chemical Properties of The Studied Cropping Systems

Particle size distribution analysis showed that soils of the studied area are generally dominated by sand-sized particles with the means of 732.2, 795.2 and 775.2 g kg^{-1} in the mono cropping, mixed cropping and fallow fields, respectively. Clay particles followed in moderate amounts with mean values of 194.0 g kg^{-1} in the mono cropping system, 118.0 g kg^{-1} in mixed cropping system and 138.0 in the fallow land while silt content had the lowest percent composition of the soil separates, having the mean values of 72.8, 86.8 and 85.8 g kg^{-1} in the mono cropping, mixed cropping and fallow land, respectively (Table 1). The sand and silt contents were not significantly ($P < 0.05$) different while clay content differed significantly ($P < 0.05$) in both the mono and mixed cropping systems and in the fallow land (Table 1). Sandiness of the soils could be due to a combination of the sandy parent materials (coastal plain sands) and the tropical climate upon which the soils were formed. Low silt content of soils has also been previously reported in the same agroecological zone of Nigeria (Esu et al., 2008). The soil pH was 5.80 in the mono cropping system, 5.74 in mixed cropping system and 5.29 in the fallow land (Table 1), indicating strong acid to moderately acid soil reactions according to the pH ratings (Chude et al., 2012). The acidic nature of the soils of the studied area could be attributed to high degree of leaching of base cations owing to the high rainfall intensity of the humid tropics (Ojanuga and Lekwa, 2005).

Organic carbon contents decreased from a mean value of 9.25 g kg^{-1} in the mixed cropping system through 6.35 g kg^{-1} in fallow land to 4.65 g kg^{-1} in the mono cropping system with a non-significant different means ($P < 0.05$) across the cropping systems. The organic carbon values were low compared to the critical limits in soil as documented (Chude et al., 2012). The finding of higher organic carbon content in the mixed cropping relative to the mono cropping system is in tandem with that of who observed significantly higher concentrations of soil organic carbon in mixed cropping system in Brazil, compared to the corresponding mono cropping system (Llany et al., 2010). Fornara and Tilman similarly found that high-diversity grass intercrops stored more soil carbon than did monocultures (Fornara and Tilman, 2008). In Germany, it was found that mixed cropping system positively impacted soil carbon storage in a grassland environment (Steinbeiss et al., 2008). However, higher organic matter content was reported in a controlled fallow land than in mixed and mono cropping systems, which they attributed to high content of humus formed by litter falls and dead plants decaying on the surface under fallow systems (Yahaya et al., 2014)

Table 1: Soil Properties of The Studied Cropping Systems

Cropping system	Sand	Silt	Clay	OC	TN	pH	TEA	Ca	Mg	K	Na	TEB	ECEC	BS	Av. P	C/N
	($g\ kg^{-1}$)					H_2O	($cmol\ kg^{-1}$)							%	$mgkg^{-1}$	
Monocropping	735.2	92.8	172.0	5.19	0.84	5.7	0.36	5.10	2.20	0.177	0.077	7.55	7.91	95.49	15.40	6.17
Monocropping	695.2	72.8	232.0	6.58	0.96	5.9	0.56	0.82	0.82	0.119	0.119	1.35	1.91	70.78	13.79	6.85
Monocropping	755.2	52.8	192.0	2.59	0.62	5.8	1.32	6.30	6.30	0.222	0.222	10.02	11.34	88.37	14.35	4.17
Monocropping	745.2	72.8	182.0	4.22	0.45	5.8	0.74	1.60	1.60	0.230	0.230	3.19	3.93	81.17	7.82	9.37
Mean	**732.2**	**72.8**	**194.0**	**4.65**	**0.72**	**5.80**	**0.75**	**3.46**	**3.46**	**0.19**	**0.09**	**5.53**	**6.27**	**83.95**	**12.84**	**6.64**
Mixed Cropping	835.2	72.8	92.0	10.37	1.29	5.8	1.36	5.30	2.70	0.206	0.107	8.31	9.67	85.96	14.70	8.03
Mixed Cropping	775.2	92.8	132.0	7.98	1.08	5.6	0.24	2.30	0.70	0.439	0.126	3.56	3.80	93.81	15.96	7.38
Mixed Cropping	775.2	92.8	132.0	8.79	0.89	5.8	0.20	4.50	1.60	0.222	0.067	6.38	6.58	97.09	12.32	9.87
Mixed Cropping	795.2	86.8	118.0	9.87	0.63	5.7	0.60	2.40	1.60	0.120	0.09	4.21	4.81	87.52	10.24	6.21
Mean	**795.2**	**86.8**	**118.0**	**9.25**	**0.97**	**5.74**	**0.60**	**3.63**	**1.65**	**0.125**	**0.10**	**5.62**	**6.22**	**91.10**	**13.31**	**7.87**
Fallow Land	815.2	72.8	112.0	7.58	1.05	5.27	0.84	4.10	1.40	0.062	0.029	5.59	6.43	86.95	12.11	7.21
Fallow Land	775.8	92.2	132.0	7.58	1.05	5.30	1.44	2.80	0.50	0.145	0.092	3.53	4.97	72.18	8.61	7.21
Fallow Land	735.2	92.8	172.0	4.99	0.83	5.29	2.20	4.52	1.68	0.094	0.124	6.41	8.61	74.54	9.38	6.01
Fallow Land	775.2	85.8	139.0	4.23	0.60	5.28	1.49	1.10	1.40	0.800	0.160	3.46	4.95	69.89	7.90	8.71
Mean	**775.2**	**85.8**	**138.0**	**6.35**	**0.88**	**5.29**	**1.49**	**3.13**	**1.25**	**0.28**	**0.10**	**4.75**	**6.22**	**75.89**	**9.50**	**7.29**
LSD (0.05)	**92.4**	**20.50**	**4.60**	**4.60**	**1.49**	**1.42**	**0.35**	**2.49**	**0.38**	**0.20**	**0.83**	**2.75**	**0.26**	**5.87**	**5.20**	**3.84**

O.C=Organic Carbon, TN=Total Nitrogen, TEA=Total exchangeable acidity, B.S=Base Saturation, Av. P=Available Phosphorus, C/N=Carbon-Nitrogen ratio, TEB=Total exchangeable bases, ECEC=Effective cation exchange capacity.

Total nitrogen values in the studied cropping systems and fallow land varied from 0.45 - 1.96 $g\ kg^{-1}$ (mono cropping system), 0.63 - 1.29 $g\ kg^{-1}$ (mixed cropping system) and 0.60 - 1.05 $g\ kg^{-1}$ (fallow land) (Table 1). The mean values of the total N followed similar trend to that of the organic C, where the highest and lowest values were recorded in the mixed cropping and mono cropping systems, respectively. Again, the total N values were low compared to the ratings (Chude et al., 2012). Some researchers attributed the main causes of N deficiency in tropical soils to soil degradation processes including intense leaching, volatilization and erosion due to high rainfall as nitrogen is very mobile (Isirimah et al., 2003). The occurrence of highest mean value of total N in the mixed cropping system (0.97 $g\ kg^{-1}$) tally with the findings of who noted that intercropping sustained soil total N compared to the mono cropping counterpart (Wang et al., 2014). Intercroppings involving legumes encourage fixation of a proportion of atmospheric N_2 which may be lacking under mono cropping systems (Jensen, 1996). The C:N ratio of the soils ranged from 4.17 – 9.37 (mono cropping system), 6.21 – 9.87 (mixed cropping system) and 6.01 – 8.71 (fallow field). The mean C/N values occurred in the order of mixed cropping (7.87) > fallow field (7.29) > mono cropping (6.64) with non-significant ($P < 0.05$) differences across the studied sites. These C/N ratios were low considering the critical limit for optimum soil biological activities placed at 25 – 35. Higher C/N ratio in a cultivated arable land compared to uncultivated forest land has also been reported (Fantaw-Yimer et al., 2007).

Available P values were generally higher than 7 $mg\ kg^{-1}$ but less than 20 $mg\ kg^{-1}$ in both the two cropping systems and the fallow land, indicating moderate P levels in line with the ratings (Chude et al., 2012). The P values was highest (13.31 $mg\ kg^{-1}$) in the mixed cropping system and lowest (9.50 $mg\ kg^{-1}$) in the fallow land, with a non-significantly ($P < 0.05$) different means across the studied sites (Table 1). Low available P values in tropical soils are often associated with the low pH of the soils as phosphorus tends to tie up with aluminum and iron oxides and become unavailable to plants in acid soils. Concentrations of the exchangeable base cations occurred in the order: Ca > Mg > K > Na across the studied sites (Table 1). Given the ratings of FDARL (1985), calcium and magnesium contents were moderate to high in the studied soils while potassium and sodium ions were low to very low. Low values of basic cations could be linked to the type of parent material, high rainfall, erosion and leaching (Chude et al., 2012).

The dominance of Ca and Mg ions in the exchange complex of tropical soils has also been widely reported (Ayolagha et al., 2012; Egboka et al., 2021). The implication of this according to is that crops can respond well to lime and fertilizer applications (Ayolagha et al., 2012). High calcium content in soils leads to increased aggregate stability as calcium acts as a binding agent aggregating particles (Baver et al., 1978). The effective cation exchange capacity (ECEC) of the soils was moderate in both the two cropping systems and the fallow land with mean values of 6.27 $cmol\ kg^{-1}$ (mono cropping), 6.22 $cmol\ kg^{-1}$ (mixed cropping) and 6.22 $cmol\ kg^{-1}$ (fallow land) while the percent base saturation (PBS) was generally high in both cropping systems and fallow field considering the critical value of 50% set (Table 1) (Landon, 1984). Low levels of cation exchange capacity in soils may be linked to low organic matter and high rate of weathering, whereas high PBS of soils reflect the dominance of basic cations in the exchange complex which is desirable for crop production (Akamigbo and Asadu, 1983).

3.2 Spore Density of AMF in The Studied Cropping Systems

A total of 486, 628 and 575 AMF spores (cumulative) were recovered from the mono cropping system, mixed cropping system and fallow land, respectively (Table 2). This follows that soils of the mixed cropping system harboured higher number of AMF spores compared to the fallow and mono cropping systems. The cumulative spore density observed in this study which occurred in the range of 486 - 628 AMF spores, compares with the cumulative spore numbers of 189 – 529 reported from soils of yam cropping systems in two agro-ecological zones of Nigeria (Dare et al., 2013). The mean AMF spore density was 123 (spores 100 g^{-1} soil) in the mono cropping system, 157 (spores 100 g^{-1} soil) in mixed cropping system and 144 (spores 100 g^{-1} soil) in the fallow land (Table 2). This shows the dominance of mycorrhizal spores in the mixed cropping system relative to the mono cropping and fallow systems.

In a study that investigated the population density of AMF under selected land use types, a group of researchers observed highest mean spore density of AMF in the uncultivated fallow field relative to the cultivated (Cassava and pineapple) land use types (Egboka et al., 2022). The higher AMF spore density in the present study recorded in the mixed cropping relative to the mono cropping and fallow systems, supports the view of who stated that fallow, the period allowed for restoration of soil fertility, is often detrimental to AMF population (Plenchette et al., 2004). A group of researcher also noted that the extent of AMF population in soil can decrease with increasing fallow durations (Duponnois et al., 2001). Mixed cropping systems which encourage combination of two or more crops in the same field, may help to maintain a high level of AMF abundance and biodiversity (Hart and Klironomos, 2002). In the contrast, the abundance and diversity of AMF reduces as cropping systems tend to mono cropping (An et al., 1993).

Mean comparison of the spore densities indicates that there was no significant ($P < 0.05$) differences in spore numbers between the mixed cropping system and the fallow land. However, spore density of the mono cropping system differed significantly ($P < 0.05$) lower from each of the mixed cropping and fallow systems (Table 2). Variations in AMF spore abundance in general, may occur as a result of factors such as cropping system and vegetation type, edaphic and climatic properties, age of host plants, spatial and temporal variations, management practices as well as the varied sporulation ability of AMF species (Muthukumar and Udaiyan, 2002; Husband et al., 2002).

Table 2: Spore Density of AMF in The Studied Cropping Systems

Cropping System	Total Spore Number (Cumulative)	Mean Spore Number (100 g^{-1} Soil)
Mono Cropping	486	123^b
Mixed Cropping	628	157^a
Fallow	575	144^a

Data were presented as cumulative sums and means of 4 replicate samples per cropping system. Means with the same letter are not significantly different at 5% probability level

3.3 AMF Spore Density and Selected Soil Properties in The Studied Cropping System

The Pearson correlation analysis between AMF spore population and selected soil properties of the studied sites indicates that the exchangeable Na^+ and K^+ contents as well as the C/N ratio correlated positively with spore density across the study sites (Table 3). The positive correlation of spore numbers with the C/N ratio was essentially, significant at ($P < 0.05$) in the mono cropping system ($r = 0.748^*$) and significant at ($P < 0.01$) in both the mixed cropping system ($r = 0.943^{**}$) and fallow land ($r = 0.647^{**}$). In contrast, soil pH (H_2O), total N, available phosphorus, and exchangeable Ca^{2+} and Mg^{2+} ions, all had negative correlations with AMF spore density. The negative correlation between the spore density and soil pH, however, was significant ($P < 0.05$) in both the mixed cropping system ($r = -0.670^*$) and fallow land ($r = 0.689^*$). Organic carbon and total porosity produced a non-significantly negative correlations with spore density in both the mixed cropping system and fallow land but had positive correlations in the mono cropping system.

Table 3: Relationship Between AMF Spore Density and Selected Soil Properties in The Studied Cropping System

Soil Properties	Correlation Coefficient (r)		
	Mono-Cropping	Mixed Cropping	Fallow
Clay (g kg^{-1})	-0.174	0.471	0.140
TP (%)	0.248	-0.514	-0.514
pH (H_2O)	-0.268	-0.670^*	-0.689^*
O.C (g kg^{-1})	0.690	-0.074	-0.124
TN (g kg^{-1})	-0.179	-0.462	-0.322
AV.P (mg kg^{-1})	-0.290	-0.181	-0.181
C/N	0.748^*	0.943^{**}	0.647^{**}
Exchangeable Ca (cmol kg^{-1})	-0.553	-0.884	-0.884
Exchangeable Mg (cmol kg^{-1})	-0.666	-0.475	-0.493
Exchangeable K (cmol kg^{-1})	0.297^*	0.076	0.086
Exchangeable Na (cmol kg^{-1})	0.035	0.492	0.423

* Significant at 0.05 probability level, ** Significant at 0.01 probability level

The negative correlation between AMF spore density and available phosphorus as observed in the present study align with previous similar studies (Emmanuel et al., 2010; Dare et al., 2013; Oehl et al., 2010; Egboka et al., 2022). Although stated that many nutrient elements do not affect AMF spore abundance significantly, it was indicated in other past studies that soil parameters such as organic carbon and pH, can affect AMF spore abundance positively (Oehl et al., 2010; Hu et al., 2013; Mohammad et al., 2013). In general, positive correlations of soil properties with AMF spore density indicate the tendency of AMF populations to increase as the levels of such properties increases in soil while negative correlations imply, that increase in such soil properties would lead to a possible decrease in spore population of AMF in the soil.

4. Conclusion

Cropping system significantly influenced concentrations of soil properties as well as the population density of AMF in the soils. The status of soil properties and spore populations of the AMF were highest in the mixed cropping system (containing crops of variable rooting characteristics), followed by the fallow land while the lowest density was recorded in the mono cropping system. Adoption of mixed cropping rather than mono cropping practices, should be encouraged in the studied area in order to enjoy maximum benefits of mycorrhizal symbiosis.

Authors Contributions

N. T. Egboka originated and conducted the research as well as wrote the manuscript. Agim, L. C. proof-read the manuscript while M. A. Okon performed the statistical analysis. Okoli, N. H. supervised the laboratory analysis as well as prepared the tables while A. I. Afangide and P. N. Okonjo carried out the field work.

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