Original Paper

Performance of maize (*Zea mays* L.) cultivars and community structure of Arbuscular Mycorrhizal Fungi in response to tillage practices and soil amendments in a derived Savanna

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Arbuscular mycorrhizal fungi (AMF) are often negatively affected in agro-systems. This investigation tested the hypothesis that community structure of AMF would vary in soil sown with maize (*Zea mays* L.) and amended with inorganic NPK fertilizer and tillage practice; that varietal variation of maize would have implication on their performance in a derived savanna. Field experiments were conducted at the Teaching and Research Farm, Federal University of Agriculture, Abeokuta in the early and late cropping seasons of 2013. Three tillage practices [conventional (CT), minimum (MT) and zero (NT)] were imposed on maize cultivars (Oba super 2 and Swan 1) in soil amended with NPK fertilizer (120 kg N/ha + 60 kg P_2O_5/ha + 60 kg K_2O/ha) and no fertilization. The treatments were in split-split arrangement fitted into randomized complete block design, replicated thrice. The main plot consisted of tillage practises, the sub plot consisted of maize varieties, while the sub-sub plot was made of soil amendments. Glomus was identified in the soil in the order NT > MT > CT (early and late seasons of 2013). Similar pattern was observed on specie richness (late season), specie evenness and diversity (both seasons). Spore count, percentage AMF colonization, specie richness, evenness and diversity were significantly higher in non-amended soil than amended. Significantly higher spore count was observed in the rhizosphere of Oba super 2 than Swan 1. Conversely more *Acaulospora* was observed in Swan 1 than Oba super 2. These evidences suggested that NT supported enriched community structure of AMF with a predominance of Glomus. Conversely, amending soil with NPK in this agroecology reversed this pattern, except for Glomus. Improved performance of maize in amended soil could have implied complimentary role of Glomus apart from nutritional. Cultivar differences of maize and seasons could have explained variation in species diversity of AMF in a derived savanna.

Keywords: *Acaulospora*, Glomus, NPK, spore count, Shannon-diversity index

1 Introduction

A change in demographic profile of the populace is going to compromise the food and nutritional security of most people, especially in the sub-Sahara region of Africa (SSA). Maize is one of the most cultivated crop in the continent that is used by man, animal and industry to meet their needs. Considering the abovementioned problem there is the need to cultivate maize intensively to increase its productivity per unit area. Tillage and application of synthetic soil amendments form a very important component in this quest for intensive cultivation of maize in the continent. Despite its agronomic advantages, in the long run tillage practices might not be sustainable. Comparatively, it had been reported that under no-till there is an improvement in the community structure of Arbuscular mycorrhizal fungi (AMF) (Melero et al., 2009), reduced hyphae breakdown and increased fungi biota in agroecosystem (Drijber et al., 2000). The presence of AMF in soils have been reported to be associated with improved nutrition (P, Zn, and Cu uptake) (Evans and Miller, 1988), and other beneficial non-nutritional effects (improved drought tolerance, enhances resistance to pest and diseases and better soil structure) (Gosling et al. 2006). The effect of tillage on the colonization of the root

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however is dependent on the soil type (Kabir et al., 1999; Mulligan et al., 1985). Few studies have been conducted in the derived Savanna on the implication of tillage on AMF community structure and infectivity of roots in soils cultivated under hybrid maize. Furthermore there have been inconsistent reports on the role of AMF in most agroecosystems (Ryan and Graham, 2002). Modern maize hybrid have been posited to be less dependent on AMF but responded better to application of inorganic fertilizer than the presence of AMF (Hetrick et al., 1993). When examined in the context of the presence of time of AMF infection, early infestation of most arable crops by AMF have been linked to reduced performance (Ryan and Graham, 2002), despite their dependency on AMF (Daniell et al., 2001). The need to resolve these conflicting reported justified the implementation of this investigation.

Application of inorganic fertilizer remains one of the sources of nutrients to maize. Other sources though desirable in the long run due to their sustainability, in the short term might not be economically attractive to farmers. There have been studies of their effects on AMF in the literature. Jensen and Jakobsen (1980) reported that application of inorganic fertilizer would reduce reliance of cultivated crops on AM symbiosis. Kahiluoto et al. (2001) indicated that under fertiliser application there would be a reduction in propagules density that would decrease AM colonization of the arable crops like maize. Furthermore and Johnson (1993) showed that increased inorganic fertilizer application would reduce AM sporulation and reduce AM community structure. Given the above evidences Wang et al. (2011) varied the combination of NPK together with other nutrient sources in their investigation to ascertain their efficacy on AM spore density and their species composition. Their investigation concluded that balanced NPK could be desirable for good yield and AM specie composition. Empirical evidence is lacking to validate this fact in other agroecological systems with different test crops, such as maize. More so, Davison et al. (2011) reported contrasting results of host preferences of AMF. Extending this logic further on the effect of cultivar differences on host preferences in a derived Savanna could allow us to further gain insight on the host-AMF symbiosis in maize in a derived Savanna.

This investigation tested the hypothesis that there would be a significant varietal variation on AMF community structure and the performance of maize cultivars in a derived Savanna. It hypothesized that tillage practices and inorganic N application would have significant effect on the AMF community structure and performance of maize cultivars in a derived Savanna.

2 Material and methods

2.1 Characterisation of site and location

Two field experiments were conducted during the early and late wet seasons of 2013 at the Teaching and Research Farms, Federal University of Agriculture, Abeokuta, Nigeria. The location lies in the South-Western Nigeria (Latitude 7° 15′ N, Longitude 3° 28′ E, 75 m a.s.l). The highest rainfall was observed in May and June (128.2 mm) in early and August (202.6 mm) in the late season. The maximum temperature during the cropping season was observed in March (29.8 °C), while the minimum was observed in August (24.3 °C).The textural class (USDA textural triangle) of the soil was sandy with a pH (McLean, 1982) that was strongly acidic (5.34). It has total nitrogen (Jackson, 1962) of 2.16 mg/kg and available phosphorus (Bray and Kurtz, 1945) of 4.0 mg/kg with soil organic carbon (Allison, 1965) of 1.76%.

2.2 Experimental treatments and design

The field experiments consisted of maize varieties [Oba Super 2 (hybrid) and Suwan-1 (open pollinated)] established under different tillage practises [conventional tillage (CT), minimum tillage (MT) and no-tillage (NT)] and amended with inorganic NPK fertilizer (120 kg N/ha + 60 kg P_2O_5/ha + 60 kg K_2O/ha) and without. The treatments were in split-split plot arrangement fitted into randomised complete block design replicated three times. Tillage methods were in the main plot. The sub plot consisted of the maize varieties with sub-sub plot made of soil amendments. The seeds were sourced from the Ogun State Ministry of Agriculture, Nigeria. Oba Super 2 is a single cross maize hybrid, with a maturity of 110 days on the average. Suwan-1 is an open pollinated variety (OPV) developed in Thailand.

2.3 Cultural operations

Conventional tillage was achieved through maximum soil disturbance. Ploughing and harrowing was conducted twice and once respectively. Conversely, minimum tillage was achieved through relatively minimal soil disturbance with hand hoe. The soil was left undisturbed throughout the duration of the experiments under no-tillage. The gross plot size was 5 × 5 m (25 m^2) and net plot size of 3 × 3 m (9 m^2). Sowing of maize seeds was conducted on May 5 and August 18, 2013 for early and late season experiments respectively. Planting was done at a spacing of 0.75 × 0.25 m at one plant per stand to give a plant population of 53,333 plants per hectare and 140 plants per plot. Conventionally and minimally tilled plots were weeded with hoes at 3 and 6 weeks after planting in both seasons while zero tilled plots were kept weed free with the application Atrazine at 3.5 kg a.i/ha as pre-emergence herbicide at planting, while Glyphosate

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applied before planting. Fertiliser was applied at 120 kg N/ha+ 60 kg P_2O_5/ha + 60 kg K_2O/ha) using inorganic NPK fertilizer (NPK 20 : 10 : 10) at 600 kg/ha at two weeks after planting (2WAP). Harvesting was done on the August 10 and November 30, 2013 for early and late season trial respectively.

2.4 Sampling and data collection

2.4.1 Soil sampling

A composite soil sample was collected randomly from the depth of 0–20 cm. It was later air dried and sieved before the evaluation of soil physical and chemical properties.

2.5 Preparation of soil and root samples

Soil samples were collected the depth of 0–20 cm from each plots. Collected root samples were rinsed in water and preserved in 50% ethanol solution. Root samples were prepared using the methods modified by Phillips and Hayman (1970). Preserved roots were washed free of ethanol, bleached in 10% KOH at 90 °C for 30 minutes. The bleached roots were rinsed to remove excess KOH and stained in acidic glycerol containing methyl blue lacto-glycerol (1 : 1 : 1 : 0.5 g) at 90 °C for 2 minutes. Prepared root samples were rinsed off staining solution with clean tap water, cut into 1 cm pieces. They were preserved with 40% glycerol solution for further viewing under compound microscope to determine percentage root colonisation.

2.6 Isolation of spores from soil and identification of AMF

Extraction of spores from soil was done using the wet sieving method described by Gerdemann and Nicolson (1963). Twenty grams of soil samples were collected from each plot and air-dried. The samples were wet sieved in order of decreasing fineness. Screenings from the sieves were washed into 50 ml centrifuge tubes using a small stream of distilled water. Tubes were centrifuged at 4000 rpm for 2 minutes. The supernatant was decanted and replaced with 50% sucrose solution, then centrifuged at earlier mentioned conditions. Spores were extracted from the supernatant by washing off sucrose solution and pouring them over a clean 0.045 mm sieve. AMF spores were collected in clean sample bottles and spores were counted under a dissecting microscope at ×80 magnification. Each spore type was mounted in polyvinyl-lactic acid-glycerine (PVLG) (Koske and Tessier, 1983) and the PVLG mixed with Melzer's reagent (Brundrett and Abbott, 1994). The spores were identified at the genus level on the basis of size, spore-wall structure, Melzer's reaction, colour and presence or absence of subtending hyphae and compared with descriptions of fungal genera according to taxonomic criteria (Pérez and Schenck, 1990).

The assignment of AMF morphotypes to families followed the consensus classification of Redecker et al. (2013).

2.7 Data collection

Spore count and percentage AMF colonisation were sampled at 2, 4 6, 8 and 12 WAP in both seasons. The total number of spore per sample was evaluated as the presence of spores from all the species in a sample. Relative species abundance was determined as the ratio of the number of spores from a particular species to the total number of spores recovered from the soil sample. Community structure of AMF was evaluated as the product of species diversity, richness and evenness. The Shannon Wiener's diversity index (H) (Shannon and Weaver, 1949) was used to determine the diversity of AMF species in each sample. Species richness was represented as total number of species recovered in each site. Specie evenness was computed by diving the Shannon diversity by the log of specie richness (Abdelhalim, Finckh, Babiker and Oehl, 2014). Percentage AMF colonisation was determined according to (Giovannetti and Mosse, 1980).

2.8 Grain yield

Harvesting was conducted at harvest maturity. Grain yield was evaluated from the net plot in the middle rows with an area of 3 × 3 m and extrapolated to grain yield kg/ha.

3 Results and discussion

Tillage had significant effect on the spore count at 6 WAP in the late season (Table 1). Tillage effect on the spore count was in the order zero > minimum > conventional tillage. Similar pattern was observed on the percentage AMF colonisation at 2 WAP (early and late seasons) and 6 WAP (late season) (Table 2). Conversely it was observed that Glomus was the most AMF specie (early and late season) in the order Conventional > minimum > zero tillage (Table 3). In the late season specie richness was in the order zero > minimum > conventional tillage (Table 4). Similar pattern was observed on specie evenness (both seasons) (Table 5) and species diversity (both seasons) (Table 6).

Inorganic fertiliser had a significant effect on spore count at all period of investigation except at 2 WAP (Table 1). Significantly higher spore count was observed in soil without soil amendments than plots with the application of NPK fertiliser. Similar pattern was observed on percentage AMF colonisation at both seasons in the 4 WAP, 6 WAP (early season), 8 WAP (late season) and 10 WAP (both seasons) (Table 2). At both seasons Glomus was significantly higher in soil amended with NPK than those without (Table 3). Conversely, in both seasons significantly higher *Gigaspora* species was observed in soils without soil amendments than those amended

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Table 1 Effect of tillage, inorganic fertiliser application rate on the spore count of AMF in soils sown with maize variety (early and late planting season, Abeokuta)

	2 WAP		4 WAP		6 WAP		8 WAP		10 WAP	
	season		season		season		season		season	
Treatment	early	late	early	late	early	late	early	late	early	late
Tillage (T)										
Conventional	6.50	7.42	33.83	30.00	64.92	77.7	122.6	98.3	137.8	99.8
Minimum	12.67	16.67	33.75	33.67	74.83	113.9	124.5	130.9	140.3	127.2
Zero	9.42	9.42	28.92	28.42	67.50	116.5	105.5	131.9	124.9	131.3
LSD	4.412	4.254	NS	NS	NS	23.76	NS	0.2441	NS	15.99
Fertilizer (F)										
without	9.39	9.72	34.67	33.67	74.50	116.1	126.2	133.6	143.2	132.9
NPK fertilizer	9.67	9.094	29.67	27.72	63.67	89.3	108.8	107.1	125.4	105.9
LSD	NS	NS	4.903	5.331	6.981	9.46	14.4	9.66	16.06	7.64
Variety										
Oba super 2	9.22	9.61	32.39	31.33	68.56	104.2	121.6	122.8	141.3	121.3
Suwan 1	9.83	10.06	31.94	30.06	69.61	101.2	113.5	117.9	127.3	117.5
LSD	NS	NS	NS	NS	NS	NS	7.17	5.88	5.18	4.96
T × F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T × V	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
F × V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T × F × V	NS	NS	*	NS	NS	NS	NS	NS	NS	NS

NS – not significant, LSD – least significant difference, WAP – weeks after planting,* – significant at 5% probability level, NPK fertilizer (120 kg N/ ha + 60 kg P_2O_5/ha + 60 kg K_2O/ha)

with NPK. Similar pattern was observed on *Acaulospora* species in the early season (Table 3). In both seasons unidentified AMF was observed to be significantly higher in unamended soil than amended with NPK. The order of specie richness and evenness at both seasons was unamended soil >NPK (Tables 4 and 5). Similar pattern was observed on species diversity at both seasons (Table 6). Conversely, grain yield at both seasons was in the order NPK> unamended soil (Table 7).

Significant varietal variation was observed on spore count at both seasons in 8 and 10 WAP (Table 1). Significantly higher spore count was observed in soils that had hybrid maize sown than those sown with OPV. Conversely, in the early season significantly more *Acaulospora* was observed in soils where OPV was sown than those with hybrid maize (Table 2).

Tillage and application of synthetic input form an integral component of intensification of agroecosystem. Under zero tillage the significantly increased spore count of AMF observed at 6 WAP (late season) could have been associated with the significantly higher AMF colonization than other tillage practices in the same period. Under conventional tillage the reduced root colonization could also be linked with soil inversion, burying of propagules (Kabir, 2005) and reduced volume of soil exploited by AMF (Evans and Miller 1988). Under zero tillage the increased spore count observed could also have been linked with the species diversity. While observed increased specie evenness and richness under zero tillage could have suggested increased species diversity under this tillage practice. Changes in the community structure under zero tillage could also be associated with increased labile carbon (Melero et al., 2009), reduced fluctuation in temperature (Zhang et al., 2014) and increased enzymic activities together with nutrient turnover (Frey, Elliott, and Paustian, 1999). Specie richness was observed in this study to be more in the late season than in the wet season. Similar observation was made by Tchabi et al. (2008). In their study they observed that specie richness decreased with increasing wet seasons in the tropics. Their observed specie richness was in the order Sudan > Northern guinea > Southern guinea. This could be explained by the availability of water and nutrients in the soil. Dry season is characterized by reduced precipitation and nutrient availability compared to the wet season. AMF species survive mostly in marginal soils with low fertility

Table 2 Effect of tillage, fertilizer application and variety on mycorrhizal colonization (%) of maize in 2013 early and late planting

	2 WAP		4 WAP		6 WAP		8 WAP		10 WAP	
	season		season		season		season		season	
Treatment	early	late	early	late	early	late	early	late	early	late
Tillage (T)										
Conventional	0.00	0.00	9.90	10.27	54.10	54.1	66.6	67.1	75.51	72.2
Minimum	1.11	1.66a	10.01	10.01	46.90	46.9	72.3	70.8	81.62	79.7
Zero	1.66	2.50a	8.88	8.33	47.70	38.0	62.00	53.6	73.86	68.3
LSD	0.227	1.090	NS	NS	NS	7.00	NS	NS	NS	NS
Fertilizer (F)										
without	1.29	1.66	11.66	11.29	54.0	49.4	71.2	65.7	83.11	76.8
NPK fertilizer	0.55	1.11	7.59	7.77	45.1	43.3	62.8	61.9	70.89	70.0
LSD	NS	NS	1.808	2.169	8.12	NS	NS	15.85	3.52	5.07
Variety										
Oba super 2	0.55	1.29	9.27	9.08	52.2	48.3	68.4	65.7	77.2	72.5
Suwan 1	1.29	1.48	9.99	9.99	46.9	44.3	65.6	61.9	76.8	74.2
LSD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T × F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T × V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F × V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T × F × V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – not significant, LSD – least significant difference, WAP – weeks after planting,* – significant at 5% probability level, NPK fertilizer (120 kg N/ ha + 60 kg P_2O_5/ha + 60 kg K_2O/ha)

status (Ratnayake, Leonard and Menge, 1978). The most predominant specie of AMF under conventional tillage was Glomus. Increasing land intensification resulted in changes in specie composition in the order Glomus > Aculospora > *Gigaspora* in the study conducted by Tchabi et al. (2008). The persistence of Glomus specie under land intensification was reported to be linked with the speed and intensity of their spore formation and their rapidity in colonizing the root (Oehl et al., 2003). Other reasons provided for the survival of Glomus species under conventional tillage was linked with anastomosis, the fusion of their hyphae under soil disturbance. Increased anastomosis of Glomus species under conventional tillage had been associated with reduced disruption of hyphae network (Sbrana et al., 2011).

The percentage of AMF colonization in the root of maize with no fertilizer application observed in the early and late seasons of the year under investigation could have been explained by the spore count during those periods. Similar observation was made by Jensen and Jakobsen (1980), where they reported that under soil amendments there was reduced reliance on AMF symbiosis in crops as indicated in the reduced percentage of AMF colonization and reduced propagules density (Kahiluoto et al., 2001; Treseder and Allen, 2002), which resulted in reduced sporulation (Johnson, 1993). These earlier reported response pattern of AMF under inorganic fertilizer application have been reported not to be general in all cases as reported by Jumpponen et al. (2005). This could be explained by the dependency of the crop on AMF symbiosis (Evans and Miller, 1988), soil type and its nutrient availability (Titus and Lepš, 2000), the combination of nutrients involved and the length of soil amendment from inorganic sources. Wang et al. (2011); Wang et al. (2008) had reported that increase in spore density under long term fertilization of the field in China was in the order NP > PK > NPK. It could be speculated that such pattern of response of spore density of AMF could also have been displayed under short term soil amendment from inorganic sources in this study. There is need to provide empirical validation for the effect of different combination of macronutrients under short term studies in this agroecology. Hepper (1983) posited that in long term study of the effect of inorganic soil amendments on AMF spore density the presence of N and K could have offset the negative effect of high P in

Table 3 Effects of tillage, fertilizer and variety on AMF spore abundance (%) of maize in 2013 early and late planting season

	Glomus		*Gigaspora*		*Acaulospora*		*Scutellospora*		Unidentified	
	season		season		season		season		season	
Treatment	early	late	early	late	early	late	early	late	early	late
Tillage (T)										
Conventional	76.8	87.6	6.75	5.59	8.77	7.68	7.24	3.98	0.77	0.85
Minimum	67.4	73.5	7.48	7.80	12.94	13.41	9.91	9.40	2.06	1.74
Zero	52.8	56.6	10.58	10.25	16.66	15.01	13.09	10.16	3.38	3.30
LSD	8.24	13.46	NS	NS	NS	NS	NS	NS	NS	NS
Fertilizer (F)										
without	59.1	63.9	10.70	9.36	14.47	12.45	11.0	8.71	2.85	2.64
NPK fertilizer	72.2	81.2	5.72	6.40	11.10	11.61	9.05	6.98	1.29	1.29
LSD	4.52	13.96	3.87	2.53	3.45	NS	NS	NS	0.3226	0.602
Variety										
Oba super 2	66.5	72.3	7.96	8.37	11.85	11.56	10.48	9.09	2.495	2.10
Suwan 1	64.8	72.8	8.46	7.39	13.59	12.50	9.67	6.61	2.446	1.82
LSD	7.40	NS	NS	NS	1.96	NS	NS	NS	NS	NS
T × F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T × V	NS	NS	NS	NS	**	NS	NS	NS	NS	NS
F × V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T × F × V	NS	NS	NS	NS	*	NS	NS	NS	NS	NS

NS – not significant, LSD – least significant difference, WAP – weeks after planting, * – significant at 5% probability level, ** – significant at 1% probability level, NPK fertilizer (120 kg N/ha+ 60 kg P_2O_5/ha + 60 kg K_2O/ha)

the soil. Contrary to the short term effect of inorganic fertilizer on AMF spore density, the observed increase of this variable was explained to be due to the effect of inorganic fertilizer on growth of the host crop. Improved growth under this condition would have increased the supply of carbon to AMF symbionts, consequently the observed increase in AMF spore density under long term effect. Probably the presence of nutrient combination in this study could not offset the negative effect of the presence of P in the nutrient combination. Alternative explanation could be the acidic nature of the soil could have affected spore count in both seasons with the application of inorganic NPK. This observation was corroborated by the findings of Mohammad et al. (2003) in their studies. The observed changes in the community structure under NPK amendment could be associated with the specie richness and evenness compared to that of soil that was not amended in this study. Wang et al. (2011) reported that application of inorganic soil amendments in China resulted in a significant decrease in specie richness and diversity of AMF. Liu et al. (2009) further indicated that changes in community structure of AMF in their study were dependent on host phenology, edaphic factors and the habitat of host. The soil samples taken in this experiment were at the vegetative growth stage. It had earlier been reported by Schalamuk et al. (2006) that AMF species diversity increases with the growth stage. This factor could have confounded the effect of inorganic NPK amendment on the community structure in this experiment. The pH of the soil and its particle distribution are some of the edaphic factors that could have combined with NPK application in changing the community structure of AMF compared with unamended soil. Thompson (1991) reported that the activities of AMF are most pronounced in alkaline, heavy clay soil. The soil under this investigation was acidic with sandy textural class. These two factors could predispose the soil to reduced AMF species diversity compared to unamended soil in this agroecology. In this study *Acaulospora* specie of AMF was observed to be predominant in unamended soil in the early season. Tchabi et al. (2007) had earlier reported that duration of the dry season significantly changed the species diversity in favor of *Gigaspora*ceae while that of the *Acaulospora* and Glomus were reduced. This could have explained the observed pattern of species in our study with respect to the seasons. *Acaulospora* was significantly higher than other species of AMF under no soil amendments than

Table 4 Effects of tillage, fertilizer and variety on AMF species richness, evenness, Shannon Weiner diversity index and grain yield in 2013 early and late planting season

	Species richness (S)		Species evenness (E)		Shannon Weiner diversity index (H)		Grain Yield (kg/ha)	
	season		season		season		season	
Treatment	early	late	early	late	early	late	early	late
Tillage (T)								
Conventional	4.33	4.08	0.53	0.41	0.77	0.58	2251	1775
Minimum	4.50	4.50	0.65	0.62	0.98	0.92	1874	1270
Zero	4.58	4.67	0.78	0.73	1.18	1.11	1649	1724
LSD	NS	0.23	0.14	0.07	0.19	0.14	NS	NS
Fertilizer (F)								
without	4.72	4.83	0.72	0.64	1.12	1.01	1272	1333
NPK fertilizer	4.22	4.00	0.58	0.52	0.84	0.73	2577	1846
LSD	0.41	0.65	0.06	0.09	0.11	0.14	447.3	365.7
Variety								
Oba super 2	4.39	4.39	00.65	0.60	0.97	0.89	1920	1698
Suwan 1	4.56	4.44	0.65	0.51	0.99	0.84	1929	1481
LSD	NS	NS	NS	NS	NS	NS	NS	NS
T × F								
T × V	NS	NS	NS	NS	NS	NS	NS	NS
F × V	NS	NS	NS	NS	NS	NS	NS	NS
T × F × V	NS	NS	NS	NS	NS	NS	NS	NS

NS – not significant, LSD – least significant difference, WAP – weeks after planting, * – significant at 5% probability level, ** – significant at 1% probability level, NPK fertilizer (120 kg N/ha+ 60 kg P_2O_5/ha + 60 kg K_2O/ha)

those soils amended with inorganic NPK. Oehl et al., 2004 observed that the predominance of *Acaulospora* was linked to organically managed soil. This could not be substantiated in this experiment, since post-planting soil analysis was not conducted. It could be inferred that the presence of organic residue from litters could have altered this C content of the soil. This is however subject to further empirical validation. AMF specie Glomus was observed in this study to be more under inorganic NPK amendment. This is consistent with earlier studies that indicated that AMF specie composition under intensive land use was in the order Glomus > *Acaulospora* > *Gigaspora* (Tchabi et al., 2007). This observed pattern could also have been linked with the fact that *Acaulospora* sporulate later than Glomus (Oehl et al., 2004). It had been reported that N or any of the water soluble fertilizers adversely affects *Gigaspora*ceae population than earlier enumerated AMF species (Egerton-Warburton and Allen, 2000). The presence of other unidentified AMF species in this agroecology under the use of inorganic fertilizer is consistent with studies earlier conducted by Tchabi et al. (2007). In their study they were able to identify high specie richness in West Africa in varied agroecological zones under different land use. Despite the observed improved community structure under zero application of fertilizer as occasioned by their specie richness and evenness grain yield of plots treated with inorganic fertilizer was observed to be higher than those without any soil amendment, this could have suggested that changes in community structure had effect on the performance of maize under this treatment in this agroecology. Available evidence in this study could have allow us to infer that Glomus specie of AMF could have played a predominant role among other species in conferring a positive effect on the performance of maize since they were the dominant specie of AMF when the soil was amended with NPK fertilizer. The underlying role of Glomus specie in this regard could not be explicated. This position conforms to the position of Jansa et al. (2003) where he posited that effect of changes in the community structure of AMF on maize performance could not be explicated. However, Wang et al. (2011) opined that a balanced NPK is good if crop yield and together with species diversity is considered. However this was not confirmed in our own study, since it was only the performance of maize that was observed without a corresponding improvement in species diversity. The observed pattern here could also be explained by the fact that modern hybrid of maize are bred to respond to high fertilizer application with low AMF dependency (Hetrick et al., 1993). Other factors that could have explained the observed community structure changes under soil amendments and the performance of maize in this agroecology could have been the phenology of the host, nutrient availability in the soil and plant (Liu et al., 2009). The time of sampling the soil for AMF spore count was conducted at the vegetative growth stage. Increasing growth stage irrespective of the treatment imposed it was observed resulted in significant increase AMF species diversity (Schalamuk, Velazquez, Chidichimo and Cabello, 2006). This could have explained the observed pattern of AMF species diversity in this study considering the tolerance of Glomus specie in all circumstance in this agroecology. The pre-planting acidic nature of the soil of the experimental site could have affected AMF community structure (Thompson, 1991). Other line of evidence was provided by Oliveira et al. (2009), where he posited that AMF colonization in the tropics was associated more with the P efficiency in maize than soil available P. All these evidences corroborated the fact that the performance of maize under this soil was related to nutrient availability to them than changes in the community structure of AMF. The performance of maize could be explained by the fact that probably in the early season there was a reduced infestation of maize by AMF; hence the Carbon cost incurred by the host would be reduced considering reduced AMF species diversity (Graham, 2000). All these hypotheses still needed further empirical validation.

Spore count had been reported to be related to the AMF colonization in cultivated crops (Khalil, Loynachan and McNabb, 1992). The observed spore count in hybrid at the later vegetative growth stage in both cropping season could have suggested that the Carbon cost to AMF would be reduced compared to the OPV. This would have implication on the yield, though this was not established in this experiment, a pattern of higher yield in the hybrid than OPV though not significant was established in the late cropping season. This pattern was established despite the fact that modern maize hybrid were established to benefit more from fertilizer application than there dependency on AMF (Hetrick et al., 1993). However, the possibility of maize encountering low nutrient availability in the late season is high especially under low precipitation observed from August till the end of the cropping season in this investigation. Hence this is where their P use efficiency would be more germane, especially for the hybrids in the tropics. Though we could not establish the P use efficiency of the maize cultivars used we hypothesize that a high P use efficiency in hybrid maize could favor increased root exudation with increased AMF colonization (Ratnayake et al., 1978). This could have serve as a proximate mechanism for the high spore count observed under hybrid maize. This is subject to further testing. The underlying mechanism response for the significantly higher number of *Acaulospora* in OPV compared to hybrid could not be explicated in this experiment.

5 Conclusion

AMF colonization of the maize cultivars under tillage practices was in the order zero tillage > minimum > conventional tillage in both seasons. Similar pattern was observed in the spore count. It could be inferred that AMF colonization is associated with the spore count in the soil. AMF species diversity under different tillage practices also followed similar pattern. This could be linked with the observed species richness and evenness under different tillage practices. It was observed that the most dominant AMF specie was Glomus under conventional tillage in both seasons. In both seasons (4 and 8 WAP) percentage AMF was significantly higher in unamended soil than those treated with inorganic N. This pattern was also observed in the spore count. AMF species diversity was observed (both seasons) to be higher in unamended soil than those with inorganic N. In unamended soil *Gigaspora* sp was significantly more than other AMF species in both seasons. However, *Acaulospora* sp was more in the early season in unamended soil. Conversely in soil amended with inorganic N Glomus species was observed to be more than other. This observation is consistent with earlier reports in the literature, where it was observed that with increasing duration of the dry season *Acaulospora* and Glomus are lesser in the soil than. It was suggested that this specie of AMF is more resilient under intensive cropping system. In both seasons the observed performance of maize cultivar with the application of inorganic N could have suggested that modern maize are bred to be more responsive to fertilizer application than their dependency on AMF. The observed pattern of spore count at the later stage (8 and 10 WAP) in both seasons for both maize cultivars used could have suggested the growth stage dependency of AMF infestation. However, this was more pronounced in the hybrid than the OPV. The assertion that modern hybrid maize are more dependent on nutrient application might need a second look, considering the low assimilate remobilization efficiency of maize. In conditions of increasing nutrient deficiency especially at the late growth stage maize might benefit from association with AMF. This would be most pronounced if there were differences in P utilization efficiencies between hybrid and OPV. Variation in this factor would elicit differences in the release of exudates and efficacy of maize-AMF association in a derived savanna. This hypothesis is subject to further empirical validation.

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