



EFFECT OF AGRICULTURAL LIME, ORGANIC AND INORGANIC FERTILIZER ON ARBUSCULAR MYCORRHIZAL FUNGI POPULATION AND DIVERSITY IN MAIZE RHIZOSPHERE SOIL IN NIGER STATE

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ABSTRACT

Knowledge of various soil amendments influencing soil microbial community is a vital soil health indicator. A field trial was conducted at Gidan Mangoro, Minna, Niger State, using five farmers' fields to evaluate the effect of agricultural lime, organic manure (cow dung), and inorganic fertilizers (NPK 20: 10: 10, urea and SSP) on Arbuscular Mycorrhizal Fungi (AMF) population and diversity on soil cultivated to maize. Soil samples were collected before and after maize cultivation at a 0-20 cm depth using a random technique using an auger. The experimental design used was a Randomized Complete Block Design with five replicates. The Minitab package (2017) was used for statistical analysis, and mean separation was done according to the Bonferroni method at a 95 % significance level. The results revealed significant differences in arbuscular mycorrhizal spore count and diversity in response to the various soil amendments used. The application of cow dung+Inorganic fertilizer recorded a significant ($P<0.05$) spore count of 779 spores / 50 g dwt in soil cultivated to maize compared to the control, which recorded 416 spore / 50 g dwt. Acaulospora and Funneliformis species of AMF were mostly observed. However, Glomus, Gigaspora, and Rhizophagus were also present in the soil of the study area. The effects of fertilizers, especially integrated soil fertility management, on Arbuscular Mycorrhizal fungal sporulation and species diversity varies, hence the need for further precise study.

Keywords: Maize: Agriculture lime, AMF spore count, AMF diversity, Rhizosphere, Integrated Soil Fertility Management (ISFM).

INTRODUCTION

Soil degradation processes influenced by soil erosion, compaction, lack of water holding capacity (WHC), reduced cation exchange capacity (CEC), acidification, poor fertility, organic and inorganic contamination, salinisation, urbanisation and changing climatic conditions jeopardise global food stability, therefore contributing to extreme economic restrictions that entail the creation of environmentally sustainable innovations that boost soil quality and resilience (Gisladottir *et al.*, 2005). For soil health/fertility sustainability, integrated soil fertility management (ISFM) is one of the reliable technologies farmers have been encouraged to adopt recently, which implies the combination of different sources of soil amendments in small quantities to complement the limitations of each component. Arbuscular mycorrhizal fungi (AMF) are a major component of the rhizosphere microflora in natural ecosystems, which plays a significant role in ecosystems through nutrient cycling (Tabassum *et al.*, 2011). These organisms form a root symbiosis with approximately 80 % of terrestrial plant species and improve nutrient and water uptake as well as pathogen resistance of their hosts in exchange for plant-assimilated carbon (Smith and Read, 2010). Therefore, it is becoming more widely acknowledged that AMF plays a significant role in agro-ecosystem functions. Many reports have shown fertilisers' negative or positive influences on AMF biodiversity, including readily soluble P and N, organic manure, and slow release of mineral fertilisers (Mar Alguacil *et al.*, 2009). However, Zhong *et al.* (2010) confirm that readily soluble fertilisers negatively impact AMF diversity. However, organic manure and slow-release fertilisers do not suppress AMF and may stimulate the microbial population and diversity. Furthermore, changes in soil nutrient status in response to organic amendments, according to Lin *et al.* (2012), may have a stronger influence on AMF colonisation and abundance. More so, the AMF community's diversity and/or composition changes may reflect the need for specific nutrients in agricultural soils.

The microorganisms are important components of soil ecosystems that characterise soil fertility (Lueders *et al.*, 2006); thus, it is important to understand the effects of organic and inorganic fertiliser applications on soil microbial communities, Arbuscular mycorrhizal fungi (AMF), which are fundamental microorganisms for soil fertility, plant nutrition and health may play an important role in organic agriculture by compensating for the reduced use of fertilisers and

pesticides if given a conducive rhizosphere to operate, in other to sustain soil health and resilience, considering the soil amendment strategies put in place. There is scanty information concerning the diversity and population of AMF in response to the use of agricultural lime, organic, and mineral fertiliser in soil cultivated to maize in Niger State. Hence, there is a need to investigate the influence of integrated soil fertility management on AMF spore count and diversity in soil-cultivated maize in the State.

MATERIALS AND METHODS

The experiment was conducted in five farmers' fields at Gidan Mangoro, Minna, Niger State. Minna lies within Nigeria's southern Guinea savannah zone and has a sub-humid climate with a mean annual rainfall of 1248 mm and a distinct dry season of five months from November to March. The mean maximum temperature remains high at about 33.5°C, particularly in March and June (Ojanuga, 2006).

Maize variety (Oba super 11) for the trial was obtained from Farm Centre, Minna, Niger state. Soil samples were collected from 5 points of each of the farmers' fields in Gidan Mangoro using soil auger before planting and before the addition of treatments. The soil sample was mixed and bulked together to make a composite from 0-20 cm depth, which was properly labelled and taken to the Soil Science Laboratory, School of Agriculture and Agricultural Technology, the Federal University of Technology Minna, air-dried, grounded, and passed through a 2 mm mesh sieve. The composite sample was kept in a sampling bag to assess the initial physical and chemical properties of the soil using the procedures described by Agbenin (1995) to obtain the soil texture (Bouyoucous hydrometer method), pH (Potentiometric method), organic carbon (Walkley and Black, 1934), total nitrogen (Kjeldahl method), available phosphorus (Bray P1), and exchangeable bases (Ca, Mg, Na, and K) using flame photometer. The same was repeated after harvest and reported as post-harvest soil analysis.

A land area measuring 6 X 6 m² was used for the study in five farmers' fields at Gidan Mangoro. The land was cleared manually using a cutlass, and ridges were made manually using a hoe. Each field consisted of five plots with six ridges and an inter-ridge spacing of 75 cm (0.75 m). Plots were separated from one another by a 1 m alley. Treatments were laid out in a Randomized Complete Block Design with five replicates. Treatments were assigned to the plots as follows: T1 = Control (No input), T2 = NPK + Urea + SSP, T3 = Agric. lime + NPK+ Urea + SSP, T4 = Cow dung + Agric. lime + NPK+ Urea + SSP, T5 = Cow dung + NPK+ Urea +

SSP. Fertiliser rates applied per plot size (36 m²): Agricultural lime at 0.5 ton/ha = 1.8 kg, Cow dung at 5 tons/ha = 18 kg, NPK (20-10-10) fertiliser at 300 kg/ha = 1.08 kg, Urea (46 % N) at 130.4 kg/ha = 0.47 kg, SSP (18 % P₂O₅) at 167 kg/ha= 0.6 kg.

Determination and identification of Arbuscular Mycorrhizal fungi population and diversity in soil cultivated to maize:

The Soil samples were collected after harvest according to the treatments applied in three replicates and the spore of arbuscular mycorrhizal in soil was determined using wet sieving and decanting method (Gerdemann and Nicolson 1963) and the identification was done at the International Institute of Tropical Agriculture (IITA), Ibadan.

Data Analysis: All measured and calculated variables were subjected to analysis of variance using the Minitab (17) package. Treatment means were separated using Bonferroni simultaneous values were recorded.

RESULTS AND DISCUSSION

Initial Soil Physical and Chemical Properties

The physical and chemical properties of the soil (0-20 cm) at the experimental site in Gidan Mangoro, Niger State, before treatment application and maize cultivation are shown in Table 1. The soil texture at the various farmer's fields before the trial was sandy loam, with the pH of farmer's fields 1, 3, and 4 being moderately acidic while that of 2 and 5 were slightly acidic. The phosphorus content (P) of all the farmers' fields was high except for field 5, which was medium (12.15). The organic carbon content of farmer fields 2 and 4 was very low (3.71 g/kg), while farmer fields 1, 3, and 5 had low organic carbon content between 4.06-4.50 g/kg. The total nitrogen content of the entire farmer's fields was low. The exchangeable cation ranged from 3.10-6.92 among the various farmer's fields. Farmer's fields 2 and 4 had low Ca²⁺ (1.70 cmol/kg each), and farmer's fields 1, 3, and 5 recorded medium Ca²⁺ content (4.20 cmol/kg, 3.00 cmol/kg, 2.00 cmol/kg), respectively. The Na⁺ content of farmer's field 3 was very low at 0.18 cmol/kg, while farmer's fields 1, 2, 4, and 5 had high Content (0.40 cmol/kg, 0.47 cmol/kg, 0.47 cmol/kg, and 0.57 cmol/kg) respectively. The K⁺ of farmer's fields 1 and 5 were medium (0.16 cmol/kg and 0.18 cmol/kg) respectively. The Mg⁺ content of farmer's fields 3 and 5 were

medium, with 0.30 cmol/kg and 0.50 cmol/kg, respectively. The farmer's fields 1, 2, and 4 had high Mg⁺ content with 1.80 cmol/kg, 1.40 cmol/kg, and 1.40 cmol/kg, respectively.

The soil's low organic carbon, total nitrogen, Ca²⁺, pH, and other nutrients are characteristics of tropical soils, as described by Ojeniyi (2010). Soils with < 7 pH value and low levels of nutrients need to be boosted with soil amendments in the form of Agricultural lime, organic, and/or inorganic fertilisers to enhance soil health for crop production. Maise takes Nitrogen, Phosphorus, and Potassium from the soil as primary nutrients required for growth and development. Hence, there is a need for balanced nutrient balance for plant and microbial existence in an ecosystem to ensure an increase in yield and to sustain soil fertility/health.

Cow Dung Analysis

The organic manure (cow dung), as shown in Table 2, contained nitrogen (2.52 %), phosphorus (0.04 %), and Potassium (0.39 %).

Post-Harvest Soil Chemical Properties

The physical and chemical properties of soil (0-20 cm) at the study site in Gidan Mangoro regarding the treatments applied (Agricultural lime, organic fertiliser (cow dung), and inorganic fertiliser (N P K 20: 10: 10 + UREA + SSP) after maize harvest are shown in Table 2. The control (untreated) plot was moderately acidic, with a pH of 6.00, while the treated plots were neutral, with a pH ranging from 6.67 - 7.00. The slight increase in pH could be attributed to using the various amendments. The organic carbon contents of the soils were very low; the value ranged from 1.35 – 2.80. The treatments did not positively influence the total nitrogen applied compared to the control (0.15 g/kg – 0.24 g/kg). The available phosphorus contents of the farmer's field were all very low. The result showed that Na⁺ content significantly increased concerning the applied treatments while the control recorded the lowest. The K⁺ and Ca²⁺ content of the soil was highly enhanced, especially with the application of agricultural lime+Inorganic (NPK+UREA+SSP) and organic fertiliser (CD)+Inorganic fertiliser. The Mg²⁺ content of the soil was increased after harvest. The application of Agriculture lime+Inorganic fertiliser and CD+Inorganic fertiliser increased MMg²⁺ from medium to high, with the control recording the lowest value.

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Table 1: Initial Soil Properties of the Five Farmers' Fields

Sample	Sand	Clay	Silt	Textural class (g kg^{-1})	pH (water 1: 2.5)	TOC (g kg^{-1})	TN (g kg^{-1})	Avail. P (mg/kg) mg kg^{-1}	Na^+	K^+	Ca^{2+}	Mg^{2+}	ECEC
F-1	748	192	60	SL	6.0	4.06	0.48	26.66	0.40	0.16	4.20	6.92	11.22
F-2	798	152	50	SL	6.2	3.71	0.27	26.10	0.47	0.22	1.70	3.86	7.35
F-3	788	162	50	SL	6.0	4.50	0.67	21.17	0.18	0.14	3.00	3.94	8.16
F-4	798	142	60	SL	6.0	3.71	0.21	29.51	0.57	0.24	1.70	4.07	6.12
F-5	808	132	60	SL	6.2	4.41	0.20	12.15	0.47	0.18	2.00	3.10	10.82

F= Farmer's field, EC= Exchangeable cations, TOC= Total Organic Carbon, TN= Total Nitrogen, ECEC= Effective Cation Exchange Capacity,
SL= Sandy loam

Table 2. Post-harvest Soil Chemical Properties

Treatments	pH (water 1:2.5)	TOC (gkg ⁻¹)	TN (gkg ⁻¹)	Avail. P (mg/kg)	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	Exch. Acid. (cmol/kg)
Control	6.00e	1.34c	0.15a	5.75e	0.39c	0.11b	2.65c	1.35ab	0.82a
NPK+UREA+SSP	6.74c	1.43c	0.18a	11.31a	0.62ab	0.15b	2.90b	2.05a	0.90a
NPK+UREA+SSP	6.67d	1.65b	0.17a	10.29b	0.50bc	0.80a	3.35a	1.54ab	0.89a
CD+AGRIC LIME+ NPK+UREA+SSP	7.0a	2.75a	0.20a	7.70d	0.64a	0.13b	2.70c	1.85ab	0.87a
CD+ NPK+UREA+SSP	6.85b	2.77a	0.24a	8.59c	0.62ab	0.85a	3.30a	1.24b	0.89a

Means with the same letter on same column are not significantly different from each other according to Bonferroni simultaneous at 95 % CI, NPK= Nitrogen Phosphorus Potassium, SSP= Single Super Phosphate, CD= Cow Dung, TOC= Total Organic Carbon, TN= Total Nitrogen

Effect of Agricultural Lime, Organic and Inorganic Fertilizer on Arbuscular Mycorrhizal Colonization and Diversity in Soil Cultivated to Maize

This experiment revealed that soil amendments (Agriculture lime, organic fertilizer, and inorganic fertilizer) positively affected the Arbuscular mycorrhizal fungi (AMF) population and diversity in the soil of the study area. Research has expressed controversial reports on the effect of soil amendments on AMF; Nitrogen supply at the initial stage sometimes offers a potential benefit in establishing mycorrhizae (Getman-Pickering *et al.*, 2021). However, organic and mineral fertilization shows an increase and decrease in the formation of mycorrhizal associations in agro-ecosystems and general (Gryndler *et al.*, 2006). Likewise, it has been reported that Glomus species in agricultural soils have been promoted by organic fertilizer (Gryndler *et al.*, 2006; Vestberg *et al.*, 2011). However, Alquacil *et al.* (2011) reported that soil treated with both chemical and organic fertilizers slightly, but not significantly, increased the AMF richness and diversity compared to soils with chemical-only fertilizer. This is contrary to the findings in this study, where distinct significant differences were observed and attributed to a combination of fertilizer (Organic+inorganic) as compared to Inorganic only with regards to Acaulspora, Rhizophagus, and Funneliformis. It could, therefore, be speculated that the application of organic manure would instigate certain changes in the composition of the AMF community, as confirmed by Yu *et al.* (2013). AMF appears to thrive in organic matter.

Dumbrellet *et al.* (2011) suggested that maize rhizosphere soils contain abundant AMF resources compared to other ecosystems. Similar to the findings in this study, where the mycorrhiza spore count was as high (779 spores / 50 g dwt of soil), and the control had 416 spores / 50 g dwt of soil. However, it contradicted other reports (Hijri *et al.*, 2006; Wang *et al.*, 2008).

It is widely reported that different fertilization regimes could change the secretion of root exudates (Yoneyama *et al.*, 2013; Kumar *et al.*, 2016), which could alter the composition of the AMF community. This is in line with the finding of this study, where the combination of different sources of soil amendments resulted in variation in population and species of AMF found in maize rhizosphere at a certain point in time. However, from this study, a total of six mycorrhizae species were found on the farmer's field in this order: *Acaulospora*>*Funneliformis*>*Glomus*>*Gigaspora*>*Rhizophagus* and lastly *Scutellospora* as shown in Table 3. This conforms with Lumini *et al.* (2010), who suggested that maize rhizosphere soils contained abundant AMF resources compared to other ecosystems, as mentioned earlier. Arbuscular Mycorrhizal fungal species of the genus *Glomus* are often dominant in agro-ecosystems, according to Daniell *et al.* (2001) and Öpik *et al.* (2009). In this study, *Glomus* and *Gigaspora* were dominant in the maize rhizosphere, given that their population was in the control plot compared to the treated plots. However, the organic+inorganic treated plots had the genus *Acaulospora* as dominant. This was probably due to the soil's acidic condition, which aligns with the report of Aguilera *et al.* (2014, 2017) that *Acaulospora* and *Scutellospora* were dominant genera in acidic soils under wheat cropping. At the same time, Castillo *et al.* (2016) found *Acaulospora* and *Claroideo-glomus* in acidic soils. Oehlet *et al.* (2004) also reported that species belonging to certain AMF fungal genera (e.g. *Glomus*) occurred in both organic and conventional soil amendment systems in small quantities, similar to the observation in this study. *Acaulospora* and *funneliformis* appeared to be more favoured using CD+Inorganic and CD+Agric. lime+Inorganic fertilizer, resulting in the highest diversity and spore count (52.7, 21.7, and 779, 714 spores 50 g dwt) respectively. Zoe *et al.* (2021) also found that low to moderate doses of fertilizer application, especially organic fertilizer compared to inorganic, increased AMF-mediated plant growth and biocontrol ability. Though Gryndler *et al.* (2008) reported that applying organic manures negatively impacted AMF diversity. Dominant AMF species varied in conventional (*Funneliformis* spp.) and organic systems (*Claroideo-glomus* spp.) (Dai *et al.*, 2014), indicating variation of AMF efficiency with fertilizers, especially P (Cruz-Paredes *et al.*, 2017). The findings in this research agree with those of Chen Zhu *et al.* (2016), who reported that the application of organic manure was the key factor bringing about changes in AMF community composition in maize

rhizosphere. This may be due to the synergy resulting from the combination of nutrients, soil conditions, plant growth status, and AMF, supported by Guttay's (1983) report. Entry *et al.* (2002) reported that AMF sporulation would be reduced under adverse soil conditions, including extremely low soil fertility and nutrient supply imbalance, especially high or low levels of N and P and extreme pH. This implies that the colonization and diversity of AMF are not static; they depend on what is obtainable and operational in the soil system at a point in time.

CONCLUSION AND RECOMMENDATION

Integrating agricultural lime, organic manure (CD) and inorganic fertilizer (NPK+ Urea+SSP) exhibited significant differences in AMF colonization and diversity. The application of CD or Agriculture lime in combination with Inorganic fertilizer resulted in the highest spore count of 779 and 714 spores / 50 g dwt of soil from maize rhizosphere. It is therefore concluded that the combination of inorganic fertilizer with either agric. Lime or organic manure (CD) resulted in some synergy, which made the maize rhizosphere conducive to the existence, diversification, and increase of Arbuscular mycorrhizal fungi. The effect of fertilizers, especially combined fertilizers, on Arbuscular mycorrhizal fungal sporulation was different and hence requires further investigation. However, there is a need for the combination of fertilizers from different sources (agricultural lime, organic fertilizer and mineral fertilizer) to make the best use of the synergy, which, of course, will increase maize yield and enhance soil fertility/health for a sustainable agro-ecosystem.

Table 3: Effect of Agricultural Lime, Organic and Mineral Fertilizer on Arbuscular Mycorrhizal Population on Soil Cultivated to Maize

Sample	Acaulospora	Gigaspora	Scutelospora	Gloomus	Rhizophagus	Funneliformis	Spore/50 g dwt)
Control	25.9e	21.4a	5.3b	21.1a	9.1c	17.3b	416e
NPK+Urea+SSP	50.0b	6.4c	1.1e	6.4c	9.6b	15.7d	561c
Agric lime+ NPK+Urea+SSP	45.2c	11.1b	6.7a	1.1b	8.7d	17.1c	714b
CD+Agric lime+ NPK+Urea+SSP	39.0d	5.5e	2.7c	6.2d	13.6a	21.8a	523d
CD+ NPK+Urea+SSP	52.7a	6.2d	1.5d	5.6e	8.5e	21.7a	779a

Means with the same letter on same column are not significantly different from each other at according to Bonferroni simultaneous 95 % CIs

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