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**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 Sate using five farmers’ fields to evaluate the effect of agricultural lime, organic manure (cow dung), and inorganic fertilizers (N P K 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 depth of 0-20 cm with the use of auger using a random technique. The experimental design used was a Randomized Complete Block Design with 5 replicates, Minitab package (2017) was used for statistical analysis, mean separation was done according to Bonferroni simultaneous at 95 % level of significance. 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 significant (P<0.05) spore count of 779 spores / 50 g dwt in soil cultivated to maize as 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.

**Keyword: 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, salinization, urbanization and changing climatic conditions, jeopardize 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 are encouraged to adopt of recent, which implies the combination of different sources of soil amendments in small quantities; to complement the limitations of each component. Arbuscular mycorrhizal fungi (AMF) is 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 the agro-ecosystem functions. Many reports have shown the negative or positive influences of fertilizers on AMF biodiversity, including readily soluble P and N, organic manure, and slow release of mineral fertilizers (Mar Alguacil *et al.,* 2009). However, Zhong *et al.* (2010) confirm that readily soluble fertilizers have negative impacts on AMF diversity but organic manure and slow release fertilizers do not suppress AMF and may even 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 colonization and abundance. More so, changes in the AMF community's diversity and/or composition may be a reflection of the need for specific nutrients in agricultural soils.

The microorganisms are important components of soil ecosystems that characterize soil fertility (Lueders *et al.,* 2006); thus, it is important to understand the effects of organic and inorganic fertilizer 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 fertilizers 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 with regard to the diversity and population of AMF in response to the use of agricultural lime, organic and mineral fertilizer in soil cultivated to maize in Niger State. Hence, the need to investigate the influence of integrated soil fertility management on AMF spore count and diversity in soil cultivated to maize in the State.

## MATERIALS AND METHODS

The ехреrіment was соnduсtеd in five farmers’ fields at Gidan Mangoro, Minna, Niger State. Minna lies within the southern Guinea savannah zone of Nigeria 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 throughout at about 33.5oC, 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 samples Were mixed and bulked together to make a composite from 0-20 cm depth, which was properly labeled and taken to the Soil Science Laboratory, School of Agriculture and Agricultural Technology, 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 (Potentio-metric 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 cutlass, ridges were made manually using a hoe. Each field consisted of five plots with 6 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 5 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. Fertilizer 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) fertilizer 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.

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

## **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.

# RESULTS AND DISCUSSIONS

## 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 commencement of 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 were high except for field 5 where it was medium (12.15). The organic carbon content of farmer fields 2 and 4 were 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 were 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 Na+ 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 fertilizers, to enhance soil health for crop production. Maize takes up Nitrogen, Phosphorus, and Potassium from the soil as primary nutrients required for growth and development, hence the 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 on 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 with reference to the treatments applied (Agricultural lime, organic fertilizer (cow dung) and inorganic fertilizer (N P K 20: 10: 10 + UREA + SSP)) after maize harvest are shown in Table 2.

The control (untreated) plot was moderately acidic with pH 6.00 while the treated plots were neutral with pH ranging from 6.67 - 7.00. The slight increase in pH could be attributed to the use of the various amendments. The organic carbon contents of the soils were very low, the value ranged from 1.35 – 2.80. The total nitrogen was not positively influenced by the treatments applied as compared to of 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 obtained showed that Na2+ content significantly increased with regards to 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 Agriculture lime+Inorganic (NPK+UREA+SSP) and organic fertilizer (CD)+Inorganic fertilizer. The Mg2+ content of the soil was increased after harvest, infact, the application of Agriculture lime+Inorganic fertilizer and CD+Inorganic fertilizer increased Mg2+ from medium to high with the control recording the lowest value.

 **Table 1: Initial Soil Properties of the Five Farmers’ Fields**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample** | **Sand** | **Clay** | **Silt** | **Textural class** | **pH****(water 1: 2.5)** | **TOC****(g kg-1)** | **TN****(g kg-1)** | **Avail. P (mg/kg)** | **Na+** | **K+** | **Ca2+** | **Mg2+** | **ECEC** |
|  |  **(g kg-1)** | **g kg-1** | **mg kg-1** |  |  |
| 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+** | **Ca2+** | **Mg2+** | **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

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## 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) had positive effect on Arbuscular mycorrhizal fungi (AMF) population and diversity in the soil of the study area. Research have expressed controversial reports on the effect of soil amendments on AMF; Nitrogen supply at initial stage, sometimes offers a potential benefit in establishment of mycorrhizae (Getman-Pickering *et al*., 2021). However, organic and mineral fertilization shows increase and decrease in the formation of mycorrhizal associations in agro-ecosystems and in 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 where observed and attributed to 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 AMF community, as confirmed by Yu et al. (2013). AMF appears to thrive in organic matter.

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

It is widely reported that the different fertilization regimes could change the secretion of root exudates (Yoneyama *et al*., 2013; Kumar *et al*., 2016) which could alter the AMF community composition as well. This is in accordance 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 point in time. However, from this study total of six mycorrhizae species were found on the farmer’s field in this order; *Acaulospora>Funneliformis>Glomus>Gigaspora>Rhizophagus* and lastly *Scutelospora* asshown in Table 3*.* This is in conformity with Lumini *et al. (*2010) who suggested that maize rhizosphere soils contained abundant AMF resources compare to other ecosystem, 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). Likewise in this study where Glomus and Gigaspora were dominant in Maize rhizosphere in view of their population in the control plot as compared to the treated plots However, the organic+inorganic treated plots had the genus *Acaulospora* as dominant this was probably due to the soil acidic condition, which is in line with the report of Aguilera *et al*. (2014, 2017) that *Acaulospora* and *Scutellospora we*re dominant genera in acidic soils under wheat cropping. While, Castillo *et al*., (2016) found *Acaulospora* and *Claroideo-glomus* in acidic soils.

Oehl *et al.* (2004) also reported thatthough species belonging to certain AMF fungal genera (e.g. *Glomus*) occurred in both organic and conventional soil amendment systems, however in small quantity similar to the observation in this study. A*caulospora* and *funneliformis* appeared to be more favoured with the use of CD+Inorganic and CD+Agric. lime+Inorganic fertilizer, resulting in highest diversity and spore count (52.7, 21.7 and 779, 714 spore 50 g dwt) respectively. Zoe *et al*. (2021) also found that low to moderate dose of fertilizer application, especially organic fertilizer compared to inorganic, increased AMF mediated plant growth and biocontrol ability. Though Gryndler *et al.* (2008) reported that the application of organic manures had negative impacts on AMF diversity. Dominant AMF species varied in conventional (*Funneliformis* spp.) and organic systems (*Claroideoglomus* spp.), (Dai *et al*., 2014); indicating variation of AMF efficiency with fertilizers, especially P (Cruz-Paredes *et al*., 2017). The findings in this research are in agreement 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 themselves supported by Guttay (1983) report. Entry *et al.*  (2002) reported that AMF sporulation would be reduced under any adverse soil conditions including extremely low as well as high 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 is not static, it depends on what is obtainable and operational in the soil system at a point in time.

## CONCLUSION AND RECOMMENDATION

The integration of 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 level of synergy which made maize rhizosphere conducive for the existence, diversification and increase in Arbuscular mycorrhizal fungi. The effect of fertilizers, especially combined fertilizers, on Arbuscular mycorrhizal fungal sporulation are differently responded to hence require further investigation. However, there is 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 enhanced soil fertility/health for 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 | Glomus | Rhizophagus | Funneliformis | Spore/50 g dwt) |
| Conrol | 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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