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Assessment of the Effects of Arbuscular Mycorrhizal Fungi *(Glomus clarum)* and Pigeon Pea Hedgerow on the Yield of Maize and Soil Properties in Degraded Ultisols

Dania Stephen. O[1]*; Fagbola, O[2]; Iyamu, M. I[3]
1 Department of Soil Science , Ambrose Alli University, Ekpoma.
*Email- megstedania@yahoo.com
2 Department of Microbiology, Ambrose Alli University, Ekpoma.
3 Department of Agronomy, University of Ibadan, Ibadan. Fagbola8@yahoo.co.uk

Abstract
The use of the arbuscular mycorrhizal fungi (*Glomus clarum)* in ecological restoration enables its host plant to be established in degraded soil. Two years field experiment was conducted at Ekpoma, Nigeria to assessed the effects of *Glomus clarum* and pigeon pea hedgerow on soil properties, yield of maize and nitrogen fixation. A factorial experiment set up in a Randomized Complete Block Design with three replicates. Soil was analysed for both chemical and physical properties before planting and after harvest. The data collected were analysed using descriptive statistics and ANOVA at $p = 0.05$. Mycorrhizal pigeon pea hedgerow significantly ($p \leq 0.05$) increased the nitrogen, phosphorus, potassium, magnesium and calcium content of the soil. Maize cultivated with the inclusion of mycorrhiza with or without pigeon pea hedgerow was higher in growth compared to non mycorrhizal maize. Inclusion of mycorrhiza to hedgerow significantly increased the grain yield of maize which was 2,040 kg / ha compared to control with an average yield of 1,406.8 kg/ha. The grain yield of mycorrhizal hedgerow was increased by 48 % compared to non-mycorrhizal pigeon pea. Inoculation of mycorrhiza to sole pigeon pea and maize had significant higher grain yield of 2,581.4 kg / ha and 2,349.2 kg / ha respectively in the residual experiment. The residual effect of *Glomus clarum* on maize and pigeon pea hedgerow significantly ($p \leq 0.05$) increased their grain yield by 41 % and 56 % respectively compared to the control. Also, inclusion of *Glomus clarum* significantly increased the nitrogen fixation of hedgerow pigeon pea compared to the hedgerow without *Glomus clarum*. The results showed the beneficial contribution of mycorrhiza and pigeon pea hedgerow on the growth and yield of maize as well as the nutrient content of the soil.
Keywords: *Glomus clarum*, hedgerow, maize, soil properties, degraded soil

1. Introduction

High rate of nutrient depletion resulting from soil degradation is the major factor affecting crop production among tropical farmers. Land degradation refers to the reduction in the quality and productive capacity of the soil which involves physical, chemical and biological deterioration such as decline in soil fertility, organic matter, vegetation cover and biodiversity (Eswaran et al. 2001). Losses of plant nutrients from the agricultural system can be in the form of harvested product, soil erosion, gaseous losses, and leaching. The major losses of nutrients are from harvested products, and soil erosion.

Ultisols are the tropical and subtropical soils of old landscapes that have a monsoon climate and are extremely weathered and leached. They have a red, brown or yellow argillic B horizon with a base saturation of less than 50 %. The soils have a low content of organic matter with ferric and hydromorphic properties. These soils are generally of low fertility and are susceptible to erosion (Fitzpatrick, 1986). It therefore necessary to improve the fertility status of this soil for increase maize production.

To maintain a sustainable cropping system where there is high rate of soil degradation due erosion, continuous cropping as well as the cultivation of marginal land then the issue of fertility management cannot be neglected. The use of inorganic fertilizer to improve soil fertility rear among poor peasant's tropical farmers due to high cost and unavailability at the right time. These mineral fertilizers also have a negative impact on the environment. However, in organic and low-input cropping systems, a balance is sought between yield and goals that minimize impacts on the environment. Soil ecological environment for plant–microbe interactions involving colonization of different microorganisms in and around growing roots which takes place in the plant rhizosphere. These result in associative, symbiotic or parasitic interactions depending upon plant soil nutrient status, environment and the type of microorganism proliferating in the rhizosphere zone. Associative action of mycorrhizal fungi in legumes has a great impact on root, shoot development and phosphorous uptake which results in the enhancement of nodulation and nitrogen fixation (Albrecht et al. 1999). Therefore the use of biological method to improve soil fertility which is environment friendly is advocated. Arbuscular mycorrhizal fungi inoculation increases the uptake of phosphorus and other nutrients which enhanced the growth and yield of crops. Mycorrhizal fungi also play an important role in soil aggregate stability which helps to build up soil resistance against erosion. The role of arbuscular mycorrhizal fungi as phosphorus suppliers to legume root

nodules is of great relevance for effective nodulation and N_2 fixation (Requena et al., 2001).
Pigeon pea (*Cajanus cajan*) is a multipurpose legume proclaiming its value as a soil builder. Globally over a billion people in 82 countries rely on pigeon peas as a main source of protein, and it is grown as a cash crop by small farmers in Africa, India, and the Caribbean. In terms of its ecological services, pigeon pea is useful as an alley crop, in agroforestry systems, home-gardens, and as a cover crop (Valenzuela and Smith, 2002).
Pigeon pea is an excellent source of organic nitrogen and nutrient recycling. It increased organic matter, improved soil structure and quality. It is a source of food and forage for animal production systems. Pigeon peas are a rich source of carbohydrates, minerals, and vitamins. Seed protein content ranges between 18-25%, and carbohydrate content from 51-58%. Other minerals include calcium, phosphorus, magnesium, and vitamins A and C (Odeny, 2007). Pigeon peas are nodulated by a wide range of *Rhizobia* strains including *Bradyrhizobium.* Pigeon peas are considered to have greater N fixation rates, compared to other legume species, its Nitrogen fixation rates was estimated between 40- 250 kg / ha (Chikowo et al. 2004). Pigeon peas develop a deep-rooting taproot up to 2 m in depth and this system helps to break hardpans, improves water infiltration, and mines nutrients and moisture from the lower soil layers (Mafongoya *et al*., 2006). The amount of nutrients released from root decomposition amounted to over 40 kg/ ha of Nitrogen and over 80 kg/ha of Phosphorus, representing a potential valuable pool of nutrients for the following crops in the rotation (Barber and Navarro, 1994). Mycorrhizal associations enhanced the ability of pigeon peas to uptake phosphorus by a rate of 10 times compared to the uptake without root inoculation (Shibata and Yano, 2003). The roots of pigeon pea excrete organic acids such as citric, piscidic, and tartaric acid, which help to mobilize phosphorus in the soil (Sinclair, 2004). The use of pigeon pea as hedgerow with cereal crops increased phosphorus uptake of the companion cereal crops (Raghothama, 1999). The ability of pigeon pea to sequester carbon, in multiple cropping systems, is another advantage to help mitigate the effects of climate change. Carbon sequestration (increased soil C by >2.5 tons/hectare) compared to the non-pigeon pea systems (Singh et al. 2005; Snapp et al. 1998). Pigeon peas is among the most effective crop species that restores the fertility of degraded soils (Barber and Navarro, 1994). Furthermore, addition of mycorrhiza to pigeon pea base cropping system will enhance the growth and yield of the companion crop (maize) and soil quality. This practice of using pigeon pea as hedgerow with inoculation of mycorrhizal fungi is very rear. It is therefore the objectives of this research to investigate:

i. the effect of mycorrhizal fungi on the growth and yield of maize and pigeon pea
ii. the effect of mycorrhiza – pigeon pea base cropping system on soil quality and to
iii. evaluate the use of pigeon pea hedgerow on the growth and yield of maize.

2.1 *Materials and Methods*

Two years field experiment was conducted at Ekpoma, Nigeria in 2008 and the residual experiment was carried out in 2009. The location between Latitude North 6 degrees, 45 minutes, 34 seconds (6° 45' 34") and longitude East 6 degrees, 8 minutes 27 seconds (6° 8' 27" East), average annual rainfall of 1500mm and temperature between 15°C – 34°C.Top soils (0-15 cm) were collected from the site prior to each planting season, the soils were air dried, sieved and the samples were analysed for both chemical and physical properties. Particle size analysis was carried out using hydrometer method (Bouyoucous, 1962). The pH was determined in water (ratio1:1, soil: water). Organic carbon was determined by wet dichoromate method (Nelson and Sommer, 1975) and Available phosphorus by Bray extraction method (Anderson and Ingram, 1993). Total nitrogen was determined by Kjeldahl method. Exchangeable cations (potassium, calcium and magnesium) were extracted with ammonium acetate, potassium was determined by flame photometer while calcium and magnesium by atomic absorption spectrophotometer. It was a factorial experiment fitted in a Randomized Complete Block Design (RCBD) replicated three times. The factors were, 2 levels of mycorrhiza (*Glomus clarum*) (with and without) and three planting systems (sole maize, sole pigeon pea, maize-pigeon pea hedgerow). The soil was tilled, Suwan-1-SR varieties of maize and IAR&T50 long duration pigeon pea were planted. The planting distance of monoculture and intercrop maize was 50cm x 50 cm while that of pigeon pea was 1m x 1m within and between rows. *Glomus clarum* was supplied by Department of Agronomy, University of Ibadan. It was propagated in a sterile potted soil cropped with maize. The inoculant consist of a root-soil –fungus spore mixture inoculated at the rate of 1,200 kg ha^{-1} and 300 kg ha^{-1} to maize and pigeon pea respectively using subsurface application method of depth between 0 – 5cm before planting. Growth parameter measured were plant height, stem girth, number of leaves and the dry matter of shoot and grain yield. The nutrient uptake by the plants were determined by multiplying nutrient concentration in the plant tissue by the dry matter weight, that is, nutrient uptake = concentration x dry matter yield. The residual experiment was carried out in 2009 were no mycorrhizal inoculum was introduced. Nitrogen fixation was evaluated by xylem sap technique (People et al. 1989). The concentration of Ureide, nitrate and amino-N was determined by the prescribed methods above, the Relative Abundance Ureide (RUN %) and % N fixed (proportion of plant N derived from N_2 – fixation) was calculated using the following formula:

RUN% = [4 x Ureide/ (4 x Ureide + nitrate + amino-N)] x 100.

After obtaining the value of RUN%, the proportion of plant N derived from N_2 – fixation (% Pfix) was estimated as follows:
% Pfix = 2.0 (RUN – 13.5).
Calculating N_2 fixed (kg ha^{-1})
Crop N (kg ha^{-1}) = legume dry matter (kg ha^{-1}) x (% N).
Amount of N_2 fixed (kgha^{-1}) = % P fix x crop N (kgha^{-1}) x 1.5.
Statistical Analysis: Data collected from the laboratory and field experiment were analyzed using analysis of variance (ANOVA) (SAS, 1995). Duncan's multiple range test (DMRT) was used to separate the means.

3. 0 *Results*

3.1 *Soil Analysis:*

The soil pH shows gradual increase to near neutral. The initial soil (control) had a pH of 5. 95, the soil cultivated with pigeon pea had a pH of 6.20 while soil with pigeon pea inoculated with mycorrhiza had a pH of 6.40. The organic carbon was higher when mycorrhiza was introduced to pigeon pea hedgerow with value 48.7 g / kg compared to soil cultivated with sole pigeon pea with value of 31.9 g / kg and the control 15.5 g / kg (Table 1). There was increase in the value of phosphorus and potassium in soil with mycorrhizal pigeon pea hedgerow than the control. Magnesium was lower in the control with value of 1.04 cmol / kg compared to soil with pigeon pea which had a value of 2.13 cmol / kg and soil with mycorrhizal pigeon pea hedgerow had a value of 2.73 cmol / kg. Calcium value was 0.67 cmol / kg in control, soil cultivated with pigeon pea 4.32 cmol / kg while mycorrhiza + pigeon pea hedgerow was 5.21 cmol / kg. ECEC was higher in soil with mycorrhizal pigeon pea hedgerow compared to control and soil cultivated solely with pigeon pea. The textural classes of the soils used for the experiment were sandy loam.

3.2 *Growth parameters:*

The height of maize was significantly ($p \leq 0.05$) increased when mycorrhiza was inoculated to both sole and maize in pigeon pea hedgerow compared to non mycorrhizal maize in 2008 and 2009 cropping season. At the residual experiment, the height of maize in the hedgerow at eight week after planting were significantly ($p \leq 0.05$) higher compared to the heights of sole maize. The stem girths of sole and hedgerow maize were significantly ($p \leq 0.05$) higher with the inoculation of mycorrhiza compared to non mycrrhizal maize in 2008. It was also observed that inoculation of mycorrhiza to sole maize increased their stem girths compared to other treatments in 2009 (Table 2). There was no difference in height and stem girth of the hedgerow at residual experiment (Table 2).

3.3 *Grain yield:*

In 2008, the grain yield of maize in hedgerow with and without mycorrhiza inoculum were 2,040.8 kg / ha and 1,774.5 kg/ ha respectively and were significantly ($p \leq 0.05$) higher compared to sole maize without mycorrhiza with grain yield value of 1,406.8 kg / ha Mycorrhizal maize had higher grain yield compared to non mycorrhizal maize (Table 3). The above ground biomass of mycorrhizal maize was significantly ($p \leq 0.05$) higher compared to non mycorrhizal maize. The grain yield and above ground biomass of mycorrhizal pigeon pea were significantly ($p \leq 0.05$) higher both in sole and intercrop compared to non mycorrhizal pigeon pea. It was also observed that sole pigeon pea without mycorrhizal had significant higher grain yield and biomass compared to intercrop non mycorrhizal pigeon pea (Table 3). The grain yield of mycorrhizal maize in pigeon pea hedgerow in the residual experiment (2009) was significantly ($p \leq 0.05$) higher compared other treatments. The grain yield of AM+MP intercrop was 2,349.2 kg / ha, AM-MP hedgerow was 2000.4 kg / ha, AM+Sole maize was 1,500.8 kg ha, AM-Sole maize was 972.4 kg / ha. The above ground biomas of AM+MP hedgerow was 2,417.7 kg / ha, AM-MP hedgerow was 2,274.8 kg / ha, AM+Sole maize was 1,664 kg / ha, AM-Sole maize was 1,109.2 kg / ha. Maize in hedgerow without mycorrhiza was also significantly ($p \leq 0.05$) higher in grain yield and shoot biomass compared to non mycorrhizal maize. It was observed that inoculation of mycorrhiza significantly ($p \leq 0.05$) increased the grain yield and biomass of sole maize compared to sole maize without mycorrhiza (Table 4). The grain yield of AM+Sole pigeon pea was 2,581.4 kg / ha, AM-Sole pigeon pea was 1,555 kg/ha, AM+MP hedgerow was 2,361.4 kg / ha and AM-MP hedgerow 1,524 kg/ha. The dry weight of shoot AM+Sole pigeon pea was 14,414.3 kg / ha, AM-Sole pigeon pea was 14,011.3 kg/ha, AM+MP hedgerow was 14,237.7 kg / ha and AM-MP hedgerow 12,384.3 kg/ha. Sole and pigeon pea hedgerows with inoculation of mycorrhiza had significant ($p < 0.05$) higher grain yield compared to non mycorrhizal pigeon pea.

3.4 *Nitrogen fixation:*

Mycorrhizal pigeon pea had significant ($p \leq 0.05$) higher nitrogen fixation per hectare compared to non mycorrhizal pigeon pea. Mycorrhizal pigeon pea was 43% higher than non mycorrhizal sole pigeon pea and 74.4% higher than the hedgerow pigeon pea.

3.5 *Nutrient uptake:*

Maize

In the first cropping season (2008), nitrogen uptake in maize was significantly ($p \leq 0.05$) higher in mycorrhizal maize in pigeon pea hedgerow (AM+MP hedgerow) with the value of 301 kg / ha compared to other treatments; AM-MP hedgerow was 241.2 kg / ha, AM+Sole maize was 261.9 kg ha, AM-Sole maize was 208.7 kg / ha. Phosphorus uptake were not significantly different among treatments. Potassium uptake was lower in sole maize without mycorrhizal inoculum (Table 5). In the residual experiment (2009), the uptake of nitrogen was significantly higher in AM+MP hedgerow with the value of 609.3 kg / ha compared to other treatments; AM-MP intercrop was 490.5 kg / ha, AM + Sole maize was 453.9 kg ha, AM - Sole maize was 374.5 kg / ha. Phosphorus and potassium showed significant increased in mycorrhizal maize in pigeon pea hedgerow compared to other treatments. Maize inoculated with mycorrhiza was significantly ($p \leq 0.05$) higher in phosphorus uptake compared to other treatments the data are shown below; AM+MP hedgerow with the value of 46.5 kg / ha; AM-MP hedgerow was 23.9 kg / ha, AM+Sole maize was 17.0 kg / ha, AM-Sole maize was 11.4 kg / ha. Potassium uptake was significantly ($p \leq 0.05$) higher in AM+MP in maize cultivated in pigeon pea hedgerow with the value of 32.4 kg / ha compared to other treatments; AM-MP hedgerow was 21.8 kg / ha, AM+Sole maize was 13.2 kg / ha while AM-Sole maize was 9.5 kg / ha

Pigeon pea:

Mycorrhizal inoculum significantly ($p \leq 0.05$) increased the nitrogen uptake in sole pigeon pea, nitrogen was significantly($p < 0.05$) higher in AM + Sole pigeon pea with the value of 1,618 kg / ha, AM + MP pigeon pea hedgerow was 1,213.7 kg / ha, AM - MP hedgerow was 652.5 kg / ha while AM - Sole pigeon pea was 864.7 kg / ha. AM + Sole pigeon pea had the value of 113.9 kg / ha, AM - MP hedgerow value was 118. 9 kg / ha; AM + MP pigeon pea was 105.4 kg / ha and AM - Sole pigeon pea was 100.9 kg / ha of phosphorus uptake. Mycorrhizal inoculum significantly ($p \leq 0.05$) increased potassium uptake in sole pigeon pea compared to other treatments.

4.0 *Discussion*

Associative actions of mycorrhizal fungi in legumes has a great impact on root and shoot development. It improve phosphorous uptake which results in the enhancement of nodulation and nitrogen fixation (Albrecht et al.1999; Poi et al. 1989). It become imperative to carried out the study to assess the contribution of AM fungi and pigeon hedgerow to the improvement of soil properties and the yield of maize. The farmers will not only derive benefit from the pigeon pea as hedgerow but also from it grain yield which could boost their income. Pigeon pea and AM fungi increase the pH of the soil to near neutral compared to initial soil pH of 5.9 and this might be as a result of the ability of the organisms to reduce acidity of the soil. The soil pH (6.4) was increased toward neutral in 2009 compared to initial analysis pH of 5.9 in 2008, this was in accordance with the earlier work done by Heichel et al. (1991), that cultivation of pigeon pea increased soil pH toward neutral. The result shows that pigeon and mycorrhizal fungi improve the organic carbon content of the soil. This confirmed the work done by Drinkwater *et al*.(1998) that legume base intercrop reduce carbon losses and increase the accumulation of carbon. Mycorrhizal fungi improve the soil nitrogen content in 2009 during the residual experiment. This result from the mutualistic interaction that exist between mycorrhiza and rhizobia which led to increase number of nodules formation and nitrogen fixation (Hodge, 2003). There was evidence that a synergistic interaction exists in the tripartite interaction of the Rhizobium-legume-AM fungi association (Gianinazzi-Pearson and Diem, 1982). Phosphorus content of the soil was also increased by pigeon pea and mycorrhiza. This confirm the work of Hamel and Strullu, (2006), that plants directly influence soils in their quality as the main source of metabolically active and soil organic matter. The role arbuscular mycorrhizal fungi (AM fungi) in phosphorous mobilization in soils having a relatively low level of available phosphorous has been reported for cereals as well as legumes. Plants also modify the soil environment, as they are the determinant of the AMF networks development and, thus, of their influence in soil. From the result in Table 1, mycorrhiza and pigeon pea hedgerow increased potassium, calcium and magnesium content of the soil. Rousseau et al. (1994) reported that mycorrhizal hyphae can increase the absorbing surface area of the root in soil deficient of nutrient. The hypha penetrates beyond the nutrient deficient zone, readily bridge this depletion zone and grow into soil with an adequate supply of phosphorus and other nutrients thereby enriching the soil nutrient content. The inoculation of mycorrhiza to the cropping system significantly increase the growth of maize and pigeon pea. According to Olawuyi et al.(2009) and Oyetunji et al. (2009) mycorrhizal inoculum significantly improved the growth of crops such as maize and yam. The yield of maize was significantly ($p \leq 0.05$) increased with application of mycorrhiza. This was in agreement with the earlier work of Ogungbe and Fagbola, (2008) that mycorrhiza enhanced the growth and yield of maize. According to Hamel (2003), inoculation of AM fungi contribute positively to growth and development of plant. The dry matter weight of maize was significantly increased by the inoculation of mycorrhiza and this was in agreement with work done by Fagbola et al. (1998). Pigeon pea hedgerow significantly ($p < 0.05$) increase the yield of maize mostly in the second cropping season. Ledgard and Giller (1995) reported that benefits of intercrops are accrue to subsequent crops as the main transfer pathways is due to root and nodule senescence and fallen leaves. MacCoil, (1989) and Giller et al. (1994) also reported that leguminous crops can maintain and sustain soil fertility due to the nitrogen fixed and green manure or the residue retained to soil. As the maize intercrop increased in growth and yield, the sole maize decline in yield, this was due to nutrient mining and nutrient imbalance, which was earlier reported by Smaling (1993). Also, the intercrop with mycorrhizal inoculum significantly increased the growth and yield of pigeon pea and maize resulting from the interaction between mycorrhizal fungi and rhizobia. The residual effects of maize intercrop with pigeon pea significantly increased the yield of maize compared to sole maize in 2009; this was in agreement with the work done by Egbe and Kalu, (2009). Egbe and Adeyemo, (2006) also reported increase in the growth and yield of maize intercropped with pigeon pea. The leaf litter fall increased the soil organic matter and nutrient uptake which eventually enhanced the growth and yield of maize and pigeon pea. Okonofua et al. (2008) and Dania et al. (2009) also reported increase in yield of yam and maize when pigeon pea leaves/biomass were applied as manure. The inoculation of AM fungi to pigeon pea increased N_2 fixation significantly. This confirm the work of Hawkins *et al.* (2000); Barea et al. (2002) that the activities of nitrogen-fixing rhizobia with mycorrhizal fungi increase the nitrogen fixation of pigeon pea. The inoculation of mycorrhizal fungi significantly increased the nitrogen uptake of maize compared to non mycorrhizal maize. This confirmed the earlier work reported by Fagbola et al. (2005) that inoculation of mycorrhiza to mycorrhizal crop significantly increased the nitrogen uptake. The increase in nutrient uptake of inoculated interplant and alley cropped maize were higher compared to non- interplanted pigeon pea and sole maize.

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5.0 *Conclusion*

In mycorrhizae – pigeon pea based cropping system, the soil nutrient status, organic matter were significantly improved and pH was increased to near neutral.

Pigeon pea hedgerow increased the growth and yield of maize compared to the control due litter fall and the ability of pigeon pea to fix nitrogen which is been used by subsequent crop. Inoculation of mycorrhizal fungi significantly ($p \leq 0.05$) increased the yield of maize and pigeon pea in both sole and intercrop system.

The inoculation of mycorrhizal fungi (*Glomus clarum*) significantly increased the nitrogen fixation of pigeon pea. The uptake of nitrogen, phosphorus and potassium were significantly increased with the inoculation of mycorrhizae. The pigeon pea hedgerow and mycorrhizal inoculum significantly improved soil nutrient status and hence the yield of maize.

Pigeon pea - mycorrhiza base cropping system should be encouraged among farmers as these will improve the growth and yield of crops. Also soil fertility will be improved as well as income benefits from the grain of pigeon pea.

Table 1:Soil chemical and physical analytical results at Ekpoma site in 2008 and 2009

Parameters	Units	Ekpoma Control 2008	Ekpoma Pigeonpea 2009	Ekpoma Pigeonpea +mycorrhiza 2009
pH(water)		5.95	6.20	6.40
Organic Carbon	(g/kg)	15.50	31.90	48.70
Nitrogen	(g/kg)	0.30	9.40	1 1.80
Phosphorus	(mg/g)	5.31	11.64	15.26
Potassium	(cmol/kg)	0.08	0.13	0.23
Magnesium	(cmol/kg)	0.37	2.13	2.73
Calcium	(cmol/kg)	0.67	4.32	5.21
ECEC		7.50	9.04	9.61
Base saturation	%	69.34	92.01	93.34
Particle Size Analysis (g/kg)				
Sand		832	834	884
Silt		114	104	54
Clay		54	62	62
Textural Class		Loamy sand	Loamy sand	Loamy sand

Table 2: Growth of maize and pigeon pea as affected by mycorrhiza in maize – pigeon pea hedgerow under field conditions at Ekpoma in 2008 and 2009 at eight and twenty week after planting respectively.

Treatments	Height (cm) maize maize		stem girth (cm)		Height (cm) pigeon pea pigeon pea		stem girth (cm) pigeon pea	
	2008	2009	2008	2009	2008	2009	2008	2009
AM +Sole P					200.9a	214.63a	7.27a	7.27a
AM -Sole P					185.4b	218.09a	6.4b	7.38a
AM+MPhedgerow	72.38a	80.81a	6.27a	6.20a	185.3b	220.62a	6.8b	7.76a
AM- MP	62.37b	68.26b	5.20b	5.60b	172.4b	218.22a	6.3b	7.02a
hedgerow	70.02a	70.02b	6.43a	5.87b				
AM + Sole M	64.98b	50.69c	5.43b	5.18b				
AM - Sole M								

Mean values with the same letter are not significantly different at P ≤ 0.05 according to Duncan's multiple range tests. AM+= with mycorrhizal inoculum; AM- = without mycorrhizal inoculum; intercrop MP= maize – pigeon pea hedgerow; sole m= sole maize; sole P= sole pigeon pea.

Table3: Grain yield, shoot biomass of maize and pigeon pea as affected by mycorrhizal inoculum inoculum in maize – pigeon hedgerow in 2008.

Treatments	Maize		Pigeon pea	
	Yield(Kg/ ha)	Shootbiomass(Kg/ha)	Yield(Kg/ha)	Shoot biomass(Kg/ ha)
AM+Sole P			1,652.3a	5,393.3a
AM-Sole P			987.0b	3,250.1b
AM+MP hedgrow	2,040.8a	2,108.8a	1,640.3a	5,491.7a
AM-MP hedgerow	1,774.5b	1,813.2b	861.8c	2,741.7c
AM+Sole Maize	1,866.8b	1,700.8b		
AM-SoleMaize	1,406.8c	1,490.8c		

Mean values in the columns with the same letters are not significantly differentat P ≤ 0.05 according to Duncan's multiple range tests. AM + = with mycorrhizal inoculum, AM - = without mycorrhizal inoculum, MP= maize & pigeon pea hedgerow, sole M= sole maize; sole P= sole pigeon pea

Table 4: Residual effect of mycorrhizal inoculum on the grain yield, shoot biomass of maize and pigeon pea in maize – pigeon hedgerow under field conditions in 2009

Treatments	Maize		Pigeon pea		N_2 fixation kg/ha
	Yield Kg/ha	Shoot biomass kg/ha	Yield kg/ha	Shoot biomass kg/ha	
AM+Sole P			2,581.4a	14,414.3a	253.4a
AM-Sole P			1,551.0b	14,011.3a	176.7b
AM+MPhedgerow	2,349.2a	2,417.7a	2,361.4a	14,237.7a	146.9c
AM-MP hedgerow	2000.4b	2,274.8a	1,324.0b	12,384.3b	143.2c
AM+Sole Maize	1,500.8c	1,664.0b			
AM-SoleMaize	972.4c	1,109.2c			

Mean values in the columns with the same letter are not significantly different at P ≤ 0.05 according to Duncan's multiple range tests.AM + = with mycorrhizal inoculum, AM - = without mycorrhizal inoculum, MP= maize & pigeon pea hedgerow, sole M= sole maize; sole P= sole pigeon pea

Table 5: Nutrient uptake (kg/ha) of maize and pigeon pea as affected by mycorrhizal inoculum in pigeon hedgerow under field conditions

EXPERIMENT TREATMENTS	SEASON 1: MAIZE			SEASON 2: MAIZE			SEASON 1: PIGEON PEA			SEASON 2: PIGEON PEA		
	N	P	K	N	P	K	N	P	K	N	P	K
AM + Sole P							1,618.0a	8.1a	31.2a	3,188.4a	113.9a	103.8a
AM - Sole P							864.5c	6.2a	12.4b	3,474.7a	100.9b	105.8a
AM+MPhedgerow	301.0a	2.1a	10.5a	609.3a	46.5a	32.4a	1,213.7b	5.5b	16.6b	3,310.9a	105.4b	116.7a
AM - MPhedgerow	241.2b	2.7a	9.5a	490.5b	23.9b	21.8b	652.5c	3.3b	14.8b	3,449.8a	118.9a	94.1a
AM + Sole M	261.9b	2.6a	10.2a	455.9b	17.0c	13.2b						
AM - Sole M	208.7c	2.1a	7.5b	374.5c	11.4c	9.5c						

Mean values in the columns with the same letter are not significantly different at $P < 0.05$ according to Duncan's multiple range tests.AM+= with mycorrhizal inoculum; AM- = without mycorrhizal inoculum; hedgerow MP= maize – pigeon pea hedgerow; sole m= sole maize; sole P= sole pigeon pea, season 1 = 2008, season 2 = 2009.

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Biography.
[1] Stephen Okhumata Dania (PhD) megstedania@yahoo.com ;
Department of Soil Science, Faculty of Agriculture, Ambrose Alli University, Ekpoma, Edo State, Nigeria.
He is a PhD holder in Soil Science specialized in soil microbiology. He is a scientist and an Agronomist presently lecturing at Ambrose Alli University, Ekpoma, Edo State, Nigeria. His current research interest is on

harnessing the potentials and benefits of pigeon pea and mycorrhiza.

[2] Olajire Fagbola (PhD) fagbola8@yahoo.co.uk
Department of Agronomy, Faculty of Agriculture, University of Ibadan, Nigeria.

Dr. Fagbola. O. is a season scientist and an Agronomist also a lecturer at the Department of Agronomy, University of Ibadan, Nigeria. He has conducted a lot of researches among which are; effects mycorrhizal fungi on cassava, maize, water regime etc.

[3] Iyamu, M. I
Department of Microbiology, Faculty of Natural Science, Ambrose Alli University, Ekpoma,Edo State, Nigeria.

She holds a PhD in microbiology; specialization in mycology. She is a senior Lecturer in the above named department.