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Response of Maize-Pigeon Pea Intercrop to Arbuscular Mycorrhizal Fungi in Nutrient Depleted Soil

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Authors' contributions

This work was carried out in collaboration between all authors. Author SOD carried out the field experiment and write up. Author OF supervised and designed the experiment. Author MID statistical analysis and correction of manuscript. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

The role of arbuscular mycorrhizal fungi in nutrient recycling can result in the improvement of plant growth and yield in nutrient depleted soil. Two years field experiment (2008 and 2009) was conducted at Ekpoma, Nigeria to investigate the effects of mycorrhizal inoculum on maize-pigeon pea intercrop. The experiment was a 2 x 3 factorial fitted into a Randomized Complete Block Design with three replicates. Soil samples from the site were analysed for both chemical and physical properties. The land equivalent ratio was determined and data collected were analysed using descriptive statistics and ANOVA at p = 0.05. In 2008, the height and stem girth of maize were increased with the inoculation of mycorrhiza. Maize had a higher grain yield of 1,866.8 kg ha^{-1} when inoculated with mycorrhiza compared to non mycorrhizal maize with grain yield of 1,406.8 kg ha^{-1}. The grain yield was 48 % higher in mycorrhizal pigeon pea compared non-mycorrhizal pigeon pea for both the intercrop and the sole pigeon pea. The inoculation of mycorrhiza increased the shoot biomass of pigeon pea and maize. The residual effects of mycorrhizal inoculation on sole pigeon pea and maize results in higher grain yield of 2,581.4 kg ha^{-1} and 1,500.8

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kg ha^{-1} respectively in 2009. The residual effects of *Glomus clarum* increased the grain yield by 41% and 56% in maize and pigeon pea respectively. The nutrient uptake in mycorrhizal maize and pigeon pea were higher compared to non mycorrhizal maize and pigeon pea. The land equivalent ratio was greater than one which indicated the advantage of intercrop over monoculture. *Glomus clarum* significantly improved their growth, shoot biomass, grain yield and nutrient uptake of maize and pigeon pea. Intercrop maize with or without mycorrhiza had higher yield in the residual experiment compared to monoculture.

Keywords: Glomus clarum; zea mays (L); cajanus cajan; land equivalent ratio.

1. INTRODUCTION

Crop production remains central to the Agriculture of any country as man and animal depend on it for food. In the tropics, crop production is adversely affected by high rate of nutrient depletion caused by land degradation. Erosion, continuous cropping and inadequate soil fertility management practices are the major causes of decrease in soil quality and organic matter consequently decline in yield [1]. Improvement and management of soil nutrient was therefore necessary for increase crop production. The use of mineral fertilizer to improve crop yield offer farmers beneficial result. However, the high cost of mineral fertilizer due to the removal of subsidy makes its use uneconomical for poor farmers. Also mineral fertilizer does not improve soil organic matter content and it continuous application reduces crop yield [2]. For better nutrient management in the tropics, an increase use of biological potential such as the inoculation of mycorrhiza is of importance. Mycorrhiza has been found very useful in ecological restoration which enables the establishment of host plant on degraded soil and also improves the quality and health of the soil [3]. Arbuscular mycorrhizal fungi (AMF) enhanced uptake of nutrients such as phosphorus, zinc, copper, boron and molybdenum, iron and manganese from the soil [4,5]. Through the intensive exploitation of the soil volume by the root external mycelia, AM fungi can efficiently and intensively extract soluble nutrients from the soils. AM fungi enhanced the uptake of phosphorus which is important for nodules formation in legumes such as pigeon pea. Apart from AM fungi contribution, legume/cereal crop interactions may occur when nodulating plant (pigeon pea) are interplanted with non-nodulated arable crop such maize. This may result in transfer of fixed nitrogen from nodulating plant to non-nodulating crop [6]. Farmers adopt intercrop of cereals such as maize and legumes (pigeon pea) to enhance productivity and income [7]. AM fungi will further improve the soil quality which will consequently increase crop yield for profitability. Pigeon pea is used in a wide variety of cropping system. Intercropping of grain legume and cereals results in the legume deriving a greater proportion of its nitrogen from nitrogen fixation than when grown alone. However, legume dry matter production and nitrogen accumulation are usually reduced because of competition from the companion crop so that the overall amount of nitrogen fixed is less than that of sole crop of a legume [8]. The early slow growth of pigeon pea, non competitive (long duration pea) growth when intercrop with cereals such as maize, sorghum, millet make it attractive to farmers. Pigeon pea enriched the soil with over 40% nitrogen per hectare in fallen leaves during its growth. Large proportion of the nitrogen fixed by pigeon pea remains in the field which can give a substantial benefit to subsequent and cereals intercrop [9]. Maize is one of the most popular cereal and the major staple food cultivated for millions of people in Nigeria and other part of the world. It is also cultivated for animal consumption and industrial use. Maize is grown in all the agroecological zone in Nigeria and the increase in the production of maize depend on soil properties and the soil nutrient content. The inoculation of arbuscular mycorrhizal fungi

to mycorrhizal crops improved their growth and yield [10,11]. It is therefore the objective of this study to evaluate the effects of mycorrhiza on the growth and yield of maize - pigeon pea intercrop.

2. MATERIALS AND METHODS

Two years field experiment was carried out at Ekpoma, Nigeria in 2008 and 2009. The location between Latitude North 6 degrees, 45 minutes, 34 seconds (6° 45' 34") and longitude East 6 degrees, 8 minutes 27 seconds (6º 8' 27" East), average annual rainfall of 1500mm and temperature between 15ºC – 34ºC. Top soils (0-15 cm) were collected from the site prior to each planting season, the soils were air dried, sieved and were analysed for both chemical and physical properties. Particle size analysis was carried out using hydrometer method [12]. The pH was determined in water (ratio1:1, soil: water). Organic carbon was determined by wet dichoromate method [13] and Available phosphorus by Bray extraction method [14]. 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. The design was a factorial experiment fitted into a Randomized Complete Block Design (RCBD) replicated three times. The factors were two levels of mycorrhiza (with and without) and three planting systems (sole maize, sole pigeon pea, maize-pigeon pea intercrop). 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 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 at planting. *Glomus clarum* was obtained at the Department of Agronomy, University of Ibadan. Weeding was carried out manually and no mineral fertilizer was applied. Growth parameter measured were height (cm), stem girth (cm), number of leaves and the dry matter of shoot (kg $ha^{-1)}$ and grain yield (kg ha^{-1}). Nutrient uptake was determined for both maize and pigeon pea. The residual experiment was carried out in 2009 without the inoculation of *Glomus clarum.* The above parameters were also evaluated. Data collected were analysed using Anova and Duncan's multiple range test was used to separate means.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Soil analysis

The soil was slightly acidic and the pH was tending toward neutral from 5.98 to 6.40 in 2008 and 2009 respectively (Table 1). The textural class was loamy sand. The initial organic carbon content of the soil was 15.5 g kg^{-1} in 2008; pigeon pea cultivation increased the organic carbon content to 31.9 g kg^{-1} while the inclusion of mycorrhiza increased the organic carbon content to 48.7 g kg^{-1} in 2009. The nutrient elements such as nitrogen, phosphorus, potassium, magnesium and calcium of soil analysed in 2009 after the cultivation of pigeon pea and inoculation of mycorrhiza were higher than the initial nutrient values in 2008 (Table 1).

3.2 Growth Parameters

3.2.1 Height of maize and pigeon pea

There was no difference in the height of maize among treatments. However, inoculation of mycorrhiza increased the height of sole and intercrop maize compared to non-mycorrhizal maize. At eight week after planting, sole pigeon pea without mycorrhizal inoculation were taller than the pigeon pea in other treatments. At twelve and sixteen weeks after planting, pigeon pea intercropped without mycorrhiza was lower in height compared to treatments inoculated with mycorrhiza. At twenty week after planting, sole pigeon pea with mycorrhiza were taller when compared to other treatments (Table 2). It was observed that non-mycorrhizal sole maize were significantly (*p=.05*) lower in height compared to other treatments (Table 3). At five and six weeks after planting, maize intercrop with pigeon pea with and without mycorrhiza were taller compared to maize in other treatments. At seven week after planting, the heights of sole and intercropped maize with mycorrhiza were 54.87 cm and 52.40 cm and were higher than the heights of non-inoculated maize with 39.36 cm and 46.72 cm respectively. At eight week after planting, the height of intercrop maize was significantly increased with the inoculation of mycorrhiza compared to other treatments (Table 3).

3.2.2 Stem girth of maize and pigeon pea

Mycorrhizal fungi inoculation significantly (*p=.05*) increased the stem girth of sole and intercrop maize compared to maize without mycorrhiza. The stem girth of pigeon pea with or without mycorrhiza was not significantly different at four, eight and twelve weeks after planting. But at sixteen and twenty weeks after planting, mycorrhizal inoculation significantly increased the stem girth of sole pigeon pea compared to other treatments (Table 4). The result of the residual experiment shows no significant difference in stem girth of maize and pigeon pea with and without mycorrhizal inoculation (Table 5).

3.2.3 Number of leaves of maize and pigeon pea

There was no difference in the number of leaves of maize among treatments throughout their period of growth in 2008 and 2009 (Table 6 and 7). Mycorrhizal inoculation significantly (*p=.05*) increased the number of leaves of pigeon pea at twelve, sixteen and twenty weeks after planting (Table 6). At twelve week after planting, the number of leaves of monoculture pigeon pea with and without mycorrhiza was 593 and 621 which were higher compared to intercrop pigeon pea with 443 and 411. It was also observed at sixteen and twenty weeks after planting, the number of leaves was lower in pigeon pea intercrop without mycorrhizal inoculum compared to other treatments (Table 7). The inoculation of mycorrhiza influences the number of leaves of pigeon pea.

3.3 Yield Parameters

The grain yield of maize intercrop with pigeon pea with and without mycorrhiza was 2,040.0 kg ha^{-1} and 1,765.7 kg ha^{-1} while that of monoculture maize with and without mycorrhiza was 1,866.6 kg ha^{-1} and 1,4406.8 kg ha^{-1} respectively. The result shows that mycorrhizal inoculation increased the grain yield of maize. The shoot biomass was higher in mycorrhizal maize intercrop compared to maize without the inoculation of mycorrhiza. The inoculation of mycorrhiza to sole and intercrop pigeon pea increased their grain yield compared to non

mycorrhizal pigeon pea. The yields of mycorrhizal sole and intercrop pigeon pea were 1,652.3 kg ha-1 and 1,640.3 kg ha-1, non - mycorrhizal sole and intercrop pigeon pea yields were 987.0 kg ha-1 and 861.8kg / ha^{-1} respectively (Table 8). It was also observed in the residual experiment that intercropped maize with mycorrhiza had the grain yield of 2,349.2 kg ha^{-1} and was significantly higher compared to other treatments. Also, the grain yield of mycorrhizal sole maize was 1,500.8 kg ha^{-1} and it was higher than non mycorrhizal maize with grain yield of 972.4 kg ha-1. The grain yield of intercrop maize inoculated with mycorrhiza had the grain yield of 1,774.8 kg ha-1 which was higher than sole maize with or without mycorrhizal inoculation. The inoculation of mycorrhiza significantly increased the grain yield of maize in sole and intercropping system compared to non mycorrhizal maize (Table 8). Sole maize with mycorrhizal inoculum was higher in shoot biomass compared to sole maize without myorrhizal inoculum. The inoculation of mycorrhiza increased the grain yield of pigeon pea compared to pigeon pea without mycorrhiza in the residual experiment (Table 9).

3.4 Nutrient Uptake

The inoculation of mycorrhiza increase nitrogen uptake in maize intercrop compared to other treatments. Phosphorus and potassium uptake were not different among treatments. In the residual experiment, nitrogen, phosphorus and potassium uptake were higher in intercrop maize inoculated with mycorrhiza compared to other treatments. Potassium uptake in maize was significantly higher in intercrop compared to the monoculture maize (Table 10). In the first cropping season of pigeon pea, the nitrogen and potassium uptake were higher in sole and intercrop mycorrhizal pigeon pea compared to non mycorrhizal pigeon pea. Also Phosphorus uptake was higher in sole pigeon pea compared to intercrop pigeon pea. In the second cropping season, Nitrogen uptake was not different among treatments. Phosphorus uptake was significantly higher in mycorrhizal pigeon pea compared to non mycorrhizal pigeon pea. Potassium was significantly lower in intercrop pigeon pea without mycorrhizal inoculation compared to other treatments (Table 10).

3.5 Land equivalent ratio (LER)

The land equivalent ratio was greater than one which indicated that intercrop was more advantageous than sole cropping using the same hacterage of land. In 2008, inoculation of mycorrhiza to maize - pigeon pea intercrop had a higher land equivalent ratio compared to intercrop without mycorrhiza (Table 11).

3.6 Discussion

The major limitation of tropical farmers is the inability to replenish nutrients lost due to continuous cultivation of land [15]. The pre-planting soil analysis results (2008) shows that the soil was low in nitrogen, phosphorus, calcium, magnesium and potassium below the critical level. During the second season (2009), after harvesting pigeon pea, the result of the soil analysis showed increase in organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium and sodium above their critical values [16]. This indicated that cultivation of pigeon pea and inoculation of mycorrhiza increased the soil organic matter and nutrient elements due to litter fall and nitrogen fixation. Pigeon pea residues contain much carbon and nitrogen, the bacteria in the soil need both the nitrogen supplied by pigeon pea to facilitates the decomposition of crop residues in the soil and their conversion to soil building organic matter led to increasing soil organic matter [7,17]. The cultivation of pigeon pea

increased phosphorus content, this showed that pigeon pea can utilized and mined phosphorus because of its deep rooting system and this was in agreement with the work done [18,19]. The inoculation of *Glomus clarum* to pigeon pea significantly influenced its nitrogen fixing ability due to increase in nodulation. The inoculation of mycorrhiza to mycorrhizal plants like pigeon pea enhanced plant mining of phosphorus through their hyphae mostly in phosphorus deficient soil which increased the growth and yield of leguminous crops like pigeon pea. The ability of pigeon pea to fix nitrogen is a peculiar characteristic of leguminous crop due to the symbiotic rhizobia living in the roots [20].

Inoculation of arbuscular mycorrhizal fungi (AMF) significantly increased the growth and yield of pigeon pea and maize compared to the treatments without mycorrhiza, this was in agreement with earlier work done [6]. Inoculation of mycorrhizal to maize significantly improved the growth and yield of maize compared to non mycorrhizal maize, this was in agreement with earlier work done [21,22]. The mycorrhizal fungi increased the root efficiency to absorb nutrient and in nutrient depleted soil, mycorrhizal fungi develop strand in the soil and absorb phosphorus through the root hairs, thereby increase nodulation and nitrogen, this character of the fungi enhanced plant growth and yield [23]. The inoculation of mycorrhiza to pigeon pea and maize had a significant positive correlation to its growth, yield and nutrient uptake. The residual effect of mycorrhizal inoculum on maize and pigeon pea significantly increased their growths and yields compared to treatment without mycorrhiza. [24] reported that the benefits of intercrop of legumes and cereal are accrue to subsequent crops as the main transfer pathways is due to root and nodule senescence and fallen leaves which was confirmed in this experiment. It has been reported that leguminous crops can maintain and sustain soil fertility due to the nitrogen fixed and green manure [25,26]. As the maize in intercrop with pigeon pea increased in growth and yield, the sole maize decline in yield, this was due to nutrient mining and nutrient imbalance. Also, mycorrhizal inoculum significantly increased the growth and yield of pigeon and maize resulting from the interaction between mycorrhizal fungi and rhizobia. The residual effects of mycorrhiza on maize intercropped with pigeon pea significantly increased the yield of maize compared to sole maize and this was in agreement with the work done [27]. The leaf litter fall increased the soil organic matter and nutrient uptake which eventually enhanced the growth and yield of maize and pigeon pea. Similar result of increase in yield of yam and maize when pigeon pea leaves/biomass were applied as manure has been reported [28,11].

AMF can indirectly affect nitrogen availability because it enhances the uptake of phosphorus which increased nodulation of leguminous plants. The inoculation of mycorrhiza to pigeon pea increased the nutrient uptake of pigeon pea compared to other treatments without mycorrhiza. This was earlier reported [29] that mycorrhizal inoculation increased nitrogen, phosphorus and Potassium (NPK) uptake. The nutrient (nitrogen, phosphorus and potassium) uptake in pigeon pea was influenced by mycorrhizal inoculation and this was in accordance with earlier work done [30].

The land equivalent ratio was greater than one (LER>1) which showed that maize- pigeon pea intercrop was more advantageous than either sole maize or pigeon pea using the same hecterage of land, these was in accordance with the work done [31].

Table 1. Soil chemical and physical analytical results in 2008 and 2009

Parameters	Units	Ekpoma Control 2008	Ekpoma Pigeonpea 2009	Ekpoma Pigeonpea + Mycorrhiza 2009	
pH(water)		5.98	6.20	6.40	Glass electrode pH meter
Organic Carbon	(g/kg)	15.50	31.90	48.70	Wet dichromate method [13]
Nitrogen	(g/kg)	0.30	9.40	11.80	Modified kjeldahl method
Phosphorus	(mg/g)	5.31	11.64	15.26	Bray 1method [14]
Potassium	(cmol/kg)	0.08	0.13	0.23	Flame photometer
Magnesium	(cmol/kg)	0.37	2.13	2.73	Atomic absorption spectrophotometer
Calcium	(cmol/kg)	0.67	4.32	5.21	Atomic absorption spectrophotometer
Sodium		0.33	1.10	1.44	Atomic absorption spectrophotometer
ECEC	%	1.45	7.68	9.61	
Base saturation	(g/kg)	69.34	92.01	93.34	
Particle Size Analysis		-	-	-	Hydrometer method [12]
Sand		832	834	884	
Silt		114	104	54	
Clay		54	62	62	
Textural Class		Loamy sand	Loamy sand	Loamy sand	

Table 2. Height (cm) of maize and pigeon pea as affected by mycorrhiza in maize – pigeon intercrop under field conditions

Treatments	Weeks after planting (maize)					Weeks after planting (pigeon pea)				
	4	5	6	7	8	4	8	12	16	20
AM + Sole P						19.9a	49.9c	114.6a	166.6a	200.5a
AM – Sole P						19.7a	77.8a	105.9a	164.7a	185.4b
AM + MP intercrop	25.2a	25.2a	35.4a	47.2a	54.9a	20.5a	62.6b	115.7a	158.9a	185.3b
AM - MP intercrop	16.9a	16.9a	28.2a	39.4a	48.3a	26.1a	53.8b	91.4b	141.9b	172.4b
AM + Sole M	22.6a	22.6a	30.6a	42.2a	53.4a					
AM – Sole M	19.2a	19.2a	29.8a	40.9a	51.6a					
[1]SE	1.61	1.61	2.03	1.10	2.43	8.68	17.83	6.26	9.93	13.42

Mean followed by the same letter in the columns are not different at P ≤ 0.05 according to Duncan's tests. AM+ = with mycorrhizal inoculum, AM - = without mycorrhizal inoculum, MP= intercrop maize & pigeon pea, Sole m= sole maize; sole P=sole pigeon pea, [1]SE = standard Error.

Table 3. Residual effect of mycorrhiza on the height (cm) of maize and pigeon pea in maize – pigeon pea intercrop under field conditions

Treatments	Weeks after planting (maize)					Weeks after planting (pigeon pea)				
	4	5	6	7	8	4	8	12	16	20
AM+ Sole P						17.9b	42.7a	113.3a	175.3a	214.6a
AM- Sole P						27.9a	53.3a	113.6a	174.1a	218.1a
AM+ MP intercrop	18.0a	25.6a	38.0a	52.4a	80.8a	18.9b	47.1a	122.1a	175.7a	220.6a
AM- MP intercrop	16.1a	24.8a	36.9a	46.7b	68.3b	27.7a	49.1a	112.5a	172.0a	218.2a
AM+ Sole M	17.3a	23.2a	32.9a	54.8a	70.0b					
AM- Sole M	13.5b	20.1b	29.8b	39.5c	50.6c					
[1]SE	2.62	4.68	4.28	5.27	9.85	5.64	24.48	53.31	106.37	99.91

Mean followed by the same letter in the columns are not different at P ≤ 0.05 according to Duncan's tests. AM+ = with mycorrhizal inoculum, AM - = without mycorrhizal inoculum, MP= intercrop maize & pigeon pea, Sole m= sole maize; sole P=sole pigeon pea, [1]SE = Standard Error

Table 4. Stem girth (cm) of maize and pigeon pea as affected by mycorrhiza in maize – pigeon intercrop under field conditions

Treatments	Weeks after planting (maize)					Weeks after planting (pigeon pea)				
	4	5	6	7	8	4	8	12	16	20
AM + Sole P						1.2a	2.6a	4.3a	6.1a	7.3a
AM - Sole P						1.0a	1.9b	3.8a	5.0b	6.4b
AM + MP Intercrop	4.2a	4.8a	5.3a	5.7a	6.2a	1.2a	2.5a	4.2a	5.4b	6.8b
AM - MP Intercrop	2.6b	3.6b	4.2b	4.7a	5.2b	1.0a	1.9b	3.6a	4.3b	6.3b
AM + Sole M	3.9a	4.8a	5.4a	5.8a	6.4a					
AM - Sole M	2.7b	3.6b	4.6b	4.9a	5.4b					
[1]SE	0.23	0.32	0.32	0.29	0.25	0.06	0.09	0.20	0.34	0.28

Mean followed by the same letter in the columns are not different at P ≤ 0.05 according to Duncan's tests. AM+ = with mycorrhizal inoculum, AM - = without mycorrhizal inoculum, MP= intercrop maize & pigeon pea, Sole m= sole maize; sole P=sole pigeon pea, [1]SE=Standard Error.

Table 5. Residual effect of mycorrhiza on stem girth (cm) of maize and pigeon pea in maize – pigeon pea intercrop under field conditions

Treatments	Weeks after planting (maize)					Weeks after planting (pigeon pea)				
	4	5	6	7	8	4	8	12	16	20
AM +-Sole P						1.0a	1.3a	4.1a	5.5a	7.3a
AM - Sole P						1.0a	1.2a	3.8a	5.4a	7.4a
AM + MP Intercrop	3.4a	4.1a	4.5a	5.3a	5.6a	1.0a	1.2a	3.9a	5.4a	7.5a
AM - MP Intercrop	3.1a	4.0a	4.8a	5.3a	5.6a	1.0a	1.2a	3.8a	5.2a	7.0a
AM + Sole M	3.3a	4.2a	4.8a	5.3a	5.9a					
AM - Sole M	2.5a	3.5a	4.3a	4.9a	5.2b					
[1]SE	0.056	0.052	0.064	0.037	0.037	0.0015	0.0014	0.12	0.26	0.21

Mean followed by the same letter in the columns are not different at P < 0.05 according to Duncan's tests. AM+ = with mycorrhizal inoculum, AM - = without mycorrhizal inoculum, MP= intercrop maize & pigeon pea, Sole m= sole maize; sole P=sole pigeon pea,1 SE= Standard Error

Table 6. Number of leaves of maize and pigeon pea as affected by mycorrhizal inoculum in maize – Pigeon pea intercrop under field conditions

Treatments	Weeks after planting (maize)					Weeks after planting (pigeon pea)				
	4	5	6	7	8	4	8	12	16	20
AM+Sole P						20a	96a	527a	1626a	3056a
AM-Sole P						19a	101a	297b	989b	1797c
AM+MP intercrop	8a	10a	11a	12a	14a	19a	97a	511a	1597a	2617b
AM-MP intercrop	8a	10a	11a	12a	14a	18a	97a	221b	941b	1785c
AM+Sole Maize	8a	10a	11a	12a	14a					
AM-SoleMaize	8a	10a	11a	12a	14a					
[1]SE	0.00	0.00	0.30	0.00	0.00	2.04	15.81	65.22	210.75	354.81

Mean followed by the same letter in the columns are not different at P ≤ 0.05 according to Duncan's tests. AM+ = with mycorrhizal inoculum, AM - = without mycorrhizal inoculum, MP= intercrop maize & pigeon pea, Sole m= sole maize; sole P=sole pigeon pea, [1]SE= Standard Error.

Table 7. Residual effect of mycorrhizal inoculum on the number of leaves of maize and pigeon pea in maize- pigeon pea intercrop under field conditions

Treatments	Weeks after planting (maize)					Weeks after planting (pigeon pea)				
	4	5	6	7	8	4	8	12	16	20
AM+Sole P						17a	79a	593a	1540a	4137a
AM-Sole P						22a	86a	621a	1543a	3831b
AM+MP intercrop	8a	10a	11a	12a	14a	19a	85a	443b	1522a	4954a
AM-MP intercrop	8a	10a	11a	12a	14a	18a	56b	411b	1368b	3877b
AM+Sole Maize	8a	10a	11a	12a	14a					
AM-Sole Maize	8a	10a	11a	12a	14a					
[1]SE	0.078	0.137	0.075	0.011	0.012	1.26	18.64	152.84	362.74	942.28

Mean followed by the same letter in the columns are not different at P ≤ 0.05 according to Duncan's tests. AM+ = with mycorrhizal inoculum, AM - = without mycorrhizal inoculum, MP= intercrop maize & pigeon pea, Sole m= sole maize; sole P=sole pigeon pea, [1]SE= Standard Error.

Table 8. Grain yield, shoot biomass of maize and pigeon pea as affected by mycorrhizal inoculum in maize – pigeon pea intercrop under field conditions

Treatments	Maize		Pigeon pea	
	Yield(Kg ha^{-1})	Shoot biomass (Kg ha^{-1})	Yield (Kg ha^{-1})	Shoot biomass (Kg ha^{-1})
AM+Sole P			1,652.3a	5,393.3a
AM-Sole P			987.0b	3,250.1b
AM+MP intercrop	2,040.0a	2,108.8a	1,640.3a	5,491.7a
AM-MP intercrop	2,000.0a	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		
[1]SE	5.61	5.35	7.21	69.32

Mean followed by the same letter in the columns are not different at P ≤ 0.05 according to Duncan's tests.
AM+ = with mycorrhizal inoculum, AM - = without mycorrhizal inoculum, MP= intercrop maize & pigeon pea, Sole m= sole maize; sole P=sole pigeon pea, [1]SE=Standard Error.

Table 9. Residual effect of mycorrhizal inoculum on the grain yield, shoot biomass of maize and pigeon pea in maize – pigeon pea intercrop under field conditions

Treatments	Maize		Pigeon pea	
	Yield(Kg ha^{-1})	Shoot biomass (Kg ha^{-1})	Yield (Kg ha^{-1})	Shoot biomass (Kg ha^{-1})
AM+Sole P			2,581.4a	14,414.3a
AM-Sole P			1,551.0b	14,011.3a
AM+MP intercrop	2,349.2a	2,417.7a	2,361.4a	14,237.7a
AM-MP intercrop	1,774.5b	2,274.8a	1,324.0b	12,384.3b
AM+Sole Maize	1,500.8b	1,664.0b		
AM-SoleMaize	972.4c	1,109.2c		
^{1}SE	7.02	7.58	0.21	131.02

Mean followed by the same letter in the columns are not different at P ≤ 0.05 according to Duncan's tests.
AM+ = with mycorrhizal inoculum, AM - = without mycorrhizal inoculum, MP= intercrop maize & pigeon pea, Sole m= sole maize; sole P=sole pigeon pea, ^{1}SE=Standard Error.

Table 10. Nutrient uptake (kg ha^{-1}) of maize and pigeon pea as affected by mycorrhizal inoculum under field conditions

Experiment	Season 1: maize			Season 2: maize			Season 1: Pigeon pea			Season 2: Pigeon pea		
Treatments	N	P	K	N	P	K	N	P	K	N	P	K
AM + Sole P							1,618.	8.1a	31.2a	3,188.4a	113.9a	103.8a
AM - Sole P							0a	6.2a	12.4b	3,474.7a	100.9b	105.8a
AM+ Intercrop MP	301.0a	2.1a	10.5a	609.3a	46.5a	32.4a	864.5c	5.5b	16.6b	3,310.9a	105.4b	116.7a
AM - Intercrop MP	241.2b	2.7a	9.5a	490.5b	23.9b	21.8b	1,213.	3.3b	14.8b	3,449.8a	118.9b	94.1b
AM + Sole M	261.9b	2.6a	10.2a	455.9b	17.0c	13.2b	7b					
AM - Sole M	208.7b	2.1a	7.5b	374.5c	11.4c	9.5c	652.5c					
^{1}SE	131.02	0.34	1.19	60.25	3.03	2.34	135.84	0.71	2.82	419.34	13.64	13.06

Mean followed by the same letter in the columns are not different at P ≤ 0.05 according to Duncan's tests. AM+ = with mycorrhizal inoculum, AM - = without mycorrhizal inoculum, MP= intercrop maize & pigeon pea, Sole m= sole maize; sole P=sole pigeon pea, ^{1}SE = Standard Error, Season 1= 2008, Season 2= 2009

Table 11. Land Equivalent Ratio of maize – pigeon pea intercrop

Treatments	2008	2009
AM+MP intercrop	2.19a	2.26a
AM-MP intercrop	1.88b	2.47a
1SE	0.51	0.28

Mean followed by the same letter in the columns are not different at P ≤ 0.05according to Duncan's tests.
AM+ = with mycorrhizal inoculum, AM - =without mycorrhizal inoculum, MP= intercrop maize & pigeon pea
Sole m= solemaize; sole P=sole pigeon pea, [1]SE = Standard Error

4. CONCLUSION

Decomposed litters and nitrogen fixed by pigeon pea which is peculiar to leguminous crops increased the level of soil organic matter and nutrient content of the soil.

Inoculation of *Glomus clarum* to pigeon pea further increased the pH to near neutral, increased the organic matter and the essential nutrient elements in the soil.

AM Fungi inoculation increased the growth and yield of maize and pigeon pea. The yield of maize and pigeon pea were increased with 32% and 40% respectively with the inoculation of mycorrhiza. The residual effects of AM Fungi on pigeon pea and maize increased their grain yield in sole and intercropping system.

The land equivalent ratio was greater than one which indicated that it was more advantageous to intercrop maize and pigeon pea compared to sole cropping of maize or pigeon pea on the same hectare of land.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. Soil conservation for small farmers in the Humid Tropics. Soils Bulletin. 1980; number 60.
2. Kapkiyai JJ, Karanj KN, Quresh JN, Sruthson P, Woomer PL. Soil organic matter and nutrient dynamic in a Kenjan Nitisol under long-term fertilizer and organic input management. Soil Biol and Biochem. 1999;31:1773-1782.
3. Jeffries P, Gianinazzi S, Perotto S, Turnau K, Barea J. The contribution of arbuscular mycorrhizal fungi in sustainable maintenance of plant health and soil fertility. Biol and Fertil of Soils. 2003;37:1-16.
4. Lambert DH, Baker DE, Cole HJR. The role of mycorrhizae in the interactions of phosphorus with zinc, copper and other elements. SSS Am J. 1979;43:975-980.
5. Shibata R, Yano K. Phosphorus acquisition from non-labile sources in peanut and pigeon pea with mycorrhizal interaction. Appl soil Ecol. 2003;24:133-141.
6. Rao MR, Muraya P, Huxley PA. Observations of some tree root systems in agroforestry intercrop situations, and their graphical representation. Exp Agr. 1993;29:183-194.

7. Egbe OM, Adeyemo MO. Estimation of the effects of intercropped pigeon pea on the yield and yield components of maize in Southern Guinea Savannah of Nigeria. J Sust Dev Environ. 2006;2(1):107-119.
8. Mafongoya PL, Giller KE, Palm CA. Decomposition and nutrient release patterns of pruning and litter of agroforestry trees. Agroforest Syst. 1997;38:77-97.
9. Kumwenda JT, Waddington SR, Snapp SS, Jones RB, Blackie MJ. Soil fertility management research for the maize cropping system of smallholders in Southern Africa: A review Natural Resource Group Paper. 1996; 96-102. CIMMYT. Mexico. D.F.
10. Fagbola O, Oyetunji OJ, Osonubi O, Mulongoy K. Greenhouse evaluation of two woody hedgerows as affected by arbuscular mycorrhizal fungus. Soil quality and Moisture. Arch Agron Soil Sc. 2005;51(3): 335–349.
11. Dania SO, Dania MI, Fagbola O. Performances of maize as influenced by *Cajanus cajan* compost and mycorrhizal inoculation. Nig J Mycol. 2009;2(1):117–122.
12. Bouyoucos GJ. Hydrometer method improved for making particle size analyses of soil. Agron J. 1962;53:464-465.
13. Nelson DW, Sommers L E. A rapid and accurate method of estimating organic carbon in soil. Proc Indiana Acad Sc. 1975; 84:456-462.
14. Anderson JM, Ingram JS. Tropical soil biology and fertility. A hand book of methods. Information Press Eynsham. 1993;10-85.
15. Mokwunye AU, De Jager, Smaling EMA. Restoring and maintaining the productivity of West Africa Soils: Key to sustainable development. International Fertilizer Development Centre (IFDC). Muscle Shoals, Alabama. 1996;94.
16. Enwenzor WU, Udo EJ, Usorah NJ, Ayotade KA, Adepetu JA, Chude VO, Holland NV. Fertilizer use and management practices for crops in Nigeria. Fertilizer Procurement and Distribution Division, Federal Ministry of Agricultural Wastes Resources and Rural Development, Nigeria, Lagos. 1989;1 – 24.
17. Hayat R, Safdar A, Muhammed TS Chatha HT. Biologal nitrogen fixation of Summer legumes and their residual effects on subsequent rainfed wheat yield. Pakinstan J Bot. 2008;40(2):711-722.
18. Ishikawa S, Adu-Gyamfi JJ, Nakamura T, Yoshihara T, Wantanabe T, Watgatsuma T. Genotype variability in phosphorus solublizing activity of root exudates by pigeon pea grown in low nutrient environments. Plant Soil 2006;245:71-81.
19. Vesterager JM, Nielsen NE, Hogh-Jensen H. Variation in phosphorus uptake and use efficiencies between pigeon pea genotypes and cowpea. J Plant Nutr 2006;29:1869-1888.
20. Soil quality-Agronomy Technical note number 6. Legumes and soil quality. USDA, Natural resources conversion service. Soil quality institute 411 S. Donahore Dr. Auburn, AL 36832334-844-4741X-177; 1998.
21. Oyetunji OJ, Fagbola O, Afolayan ET. Effects of Abuscular mycorrhizae and soil amendments on nutrient accumulation, water status and Chlorophyll Production of Yam. Nig J Mycol. 2009;2(1):209–220.
22. Olawuyi OJ, Babatunde FE, Akinbode EA, Odebode AC, Olakojo SA, Adesoye AI. Performance of Maize Genotypes and Arbuscular Mycorrhiza in Samara District of South-West Region of Doha-Qatar. 4th Annual Conference of Mycological Society of Nigeria. Ekpoma, 19th – 22nd September; 2010. Book of Abstract, pp.16.
23. Muok BO, Matsumura A, Ishii T, Odee DW. The effect of intercropping *Sclerocarya birrea* (A. Rich.) Hochst., millet and corn in the presence of arbuscular mycorrhizal fungi. Afr J Biotech. 2009;8(5):807 – 812.
24. Ledgard SJ, Giller KE. Atmospheric N2 – fixation as an alternative nitrogen source. 443 – 486. In: Bacon. P. (ed). Nitrogen fertilization and the environment. Marcel Dekker. New York; 1995.

25. MacColl D. Studies on Maize (*Zea mays* L.) at Bunda. Malawi II. Yield in Short rotation with legumes. Exp Agr. 1989;25:367- 374.
26. Giller KE, McDonagh JF, Cadisch G. Can biological nitrogen fixation sustain agriculture in the tropics? In Syers, JK, Rimmar, DL (Eds). CAB Int. Wallingford, England. Soil Sc and Sust Land Manag Trop. 1994;173-191.
27. Egbe OM,Kalu BA. Evaluation of Pigeon{*Cajanus cajan*(L.) Millsp.}Genotype for intercropping with tall sorghum (sorghum bicolor (L.) Moench) in southern guinea savanna of Nigeria. Asian Res Publishing Network J Agr and Biol Sc. 2009;2:54-67.
28. Okonofua BU, Ogboghodo IA, Chokor JU, Agbi I. The effects of application of *Cajanus cajan* biomass on the yield of *Dioscorea rotunata* inter cropped with maize. Legume Res. 2008;31(1). Accessed: 3 March 2010. Available: http://www.indianjournals.com/ijor.aspx.
29. Schimel JP, Bennett J. Nitrogen minrealization: Challenges of a changing paradigm Ecol. 2004;85:591–602.
30. Kumar Rao JVDK, Dart PJ. Nodulation, nitrogen fixation and nutrient uptake in pigeon pea of different maturity groups. Plant and Soil. 1987;99:255-266.
31. Dasbak MA, Asiegbu JE. Perfromance of pigeon pea genotype intercropped with maize under humid tropical ultisol conditions. J Animal and Plant Sci. 2009;4(2):329-340.

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