J. BIOL. ENVIRON. SCI.,
2020, 14(42), 99-106

Original Research Article

Mycorrhizal Colonization Rate of Some Crops Grown in Kano, Nigeria

Bala Zayyanu Manga[1*] and Safianu Rabiu[1]
[1]Department of Biological Sciences, Bayero University Kano, P.M.B. 3011, Kano, 700241, NIGERIA

Received: 16.09.2020; Accepted: 06.10.2020; Published Online: 25.12.2020

ABSTRACT

This research looked into the fungal richness of some crops grown in Kano, with objectives that included colonization level of the fungi and soil parameters. All data were analyzed using descriptive and inferential statistics using SPSS software. All the crops show significant levels of colonization with Groundnut having the highest colonization (37%) at the pre-flowering stage and the least colonization was observed at the flowering stage of Millet (12.6%) followed by the flowering stage of Groundnut (21.2%). Soil physicochemical properties were more favourable for Cowpea and foliar concentration higher for Groundnut plant. The correlation between root length colonization percentage and soil parameters was calculated by Spearman's rank correlation coefficient r, and correlation was moderate with temperature and pH (-0.396 and 0.301 respectively), and low with other parameters.

Keywords: Fungi, Root length, Soil parameter

INTRODUCTION

Within the last 20 to 30 years, there has been a growing awareness that most vascular plants could not grow and reproduce successfully without the assistance provided by networks of fungi in the soil. This association between plant and fungus is called mycorrhiza (plural: mycorrhizae). In most instances, the relationship is mutualistic or symbiotic (Okon and Solomon 2014). The plant provides sugars and carbohydrates to the fungus and in return the fungus uses its branched, thread-like hyphae (mycelium) to gather water, minerals, and nutrients for the plant (Okon and Solomon 2014). Mycorrhizal fungi greatly expand the reach of the plant's root systems and are especially important in helping them gather non-mobile nutrients such as phosphorus. These fungi have also been found to serve a protective role for their associated plants; they can reduce plant uptake of heavy metals and salts that may be present in the soil (Lee *et al*. 2006). Many also help protect plants from certain diseases and insects (Lee *et al*. 2006). Scientists believe that it was mycorrhizal fungi that allowed ancient vascular plants to populate the land. Of the current plant families, 95% include species that either associate beneficially with or are absolutely dependent on mycorrhizal fungi for their survival (Scharnagl 2013). A number of different types of mycorrhizas exist in nature and can be identified by the hyphal structures they form. Arbuscular mycorrhizas (AM), sometimes referred to as endomycorrhizas, are formed predominantly by the fungi of the Glomeromycota (Hailemariam and Asfaw 2013).

Groundnut, Cowpea, Millet, and Sorghum, are all agricultural crops commonly grown in Kano. Although the region has produced much of these crops to the satisfaction of its human inhabitants for a long time, there is limited information on their mycorrhizal status. The aim of this work was to compare root length colonization across the crops and sites, and to test and compare soil physicochemical properties; namely; temperature, moisture content, pH, nitrogen, phosphorus, potassium and organic carbon.

MATERIALS AND METHODS

Study area

Crop farm were cultivated at Bayero University Kano (BUK) Old and New Campuses located in Gwale and Ungogo Local Government Areas, respectively. Old campus was designated Site A, while New Campus was designated Site B.

* Corresponding author: zayyanub2@gmail.com

Sampling procedure and species selection

Sampling was done using transect method on four crops from three groups, namely; cereals, grains and legumes. The selection was carried out from two sites, Sites A and B. The sampling was done at three vegetative stages of the crops; pre-flowering (four weeks after planting), flowering and budding stage (maturation stage). The treatments were replicated five times.

Four most commonly grown crops of Kano State were selected for this study. These are *Arachis hypogaea* (groundnut), *Vigna unguiculata* (cowpea), *Pennisetum glaucum* (millet), and *Sorghum bicolor* (sorghum). Thus, this list comprised of two grains and two legume crops respectively. These seeds were from International Institute of Tropical Agriculture (IITA) and International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Kano Stations. The varieties include; Samnut-23 groundnut, IT99K-573-1-1 cowpea, Sosat millet, and Zabuwa sorghum. These crops were all field grown and were carefully uprooted with the surrounding rhizospheric soil, transferred immediately into labeled polyethylene bags and taken to the laboratory. Sampling for each crop was carried out in five randomly selected locations within the experimental site. The variables in this experiment were Time, Crops and Sites.

Microscopic determination of arbuscular mycorrhizal fungi root colonization

For detailed microscopic examination, representative root samples were carefully washed with tap water to remove soil particles, and adhering organic matter were removed with the aid of a fine brush, forceps and under a dissecting microscope. A sub-sample of the roots were then cleared and stained using modified procedure described by Brundrett *et al*. (1996); Ten grams of root material were heated to 90°C in 3% KOH for 30 minutes to soften the root, and were then bleached in alkaline H_2O_2 for 30 minutes. The roots were acidified with 0.1ml HCl for one hour and heated to 90°C with lactoglycerol trypan blue stain for 30 minutes; this was be followed by destaining in lactoglycerol for 24 hours. In the original Brundrett *et al.* (1996) procedure, the root materials are heated to 90°C in 5% KOH for 30 minutes, bleaching in alkaline H2O2 is for 30–40 minutes. Acidfication with HCl was overnight. Stained roots were examined for both external and internal hyphal structures under a compound microscope (Leica CME). Each slide examined contained 5 root pieces 2 cm long. For each crop species, five slides were prepared, such that 25 root pieces and 50 cm of root were examined per crop species. All the fungal structures were recorded and tabulated. The presence of a mantle and Hartig net were evidence of Ecto-mycorrhiza (EM) status. Roots were regarded as Arbuscular-mycorrhiza (AM) only when vesicles and/or arbuscules were found, it was Arbuscular mycorrhiza – Ectomycorrhiza when both ecto- and arbuscular mycorrhiza structures were observed in the roots of plants of the same species.

RESULTS

Root length colonization

The root length colonization is an important factor in ascertaining the richness of the soil for the growth of plants. The two sites considered in this study tend to show distinctive variability in the colonization levels of the crops. Table 1 showed the difference in colonization across the growth stages and across sites. For groundnut in Bayero University Kano Old Site, highest colonization level occurred at the Budding Stage (41.3%) which was followed by Pre-flowering Stage with 37.5% and least colonized was the Flowering Stage (21.2%). For the BUK New Site, budding stage had the highest colonization level of 36.39%, and was followed by the Flowering Stage with 33.91% and 29.70% as the least colonized as observed for the pre-flowering Stage.

For Cowpea, BUK Old Site, highest colonization level was observed at Pre-flowering Stage of the crop with 41.7% which was followed by the Budding Stage (29.6%) and the least colonized was the Flowering Stage with 28.7%. For BUK New Site however, highest colonization level was seen at the Pre-flowering Stage with 36.7%, this was followed by the Budding Stage with 33.7% and the least colonized at 29.6% which happened to be the Flowering Stage.

For Millet, highest colonization for BUK Old Site occurred at the Pre-flowering Stage with 44.6%, followed by the Flowering Stage with 29.3% and the least colonized was the Budding Stage with 26.1%.

However, for the BUK New Site, highest colonization occurred at the pre-flowering stage with 44.54%, followed by the budding stage 42.83% and 12.63% was the least colonized at the Flowering Stage.

Similarly, for Sorghum BUK Old Site, 45.6% for the Pre-flowering Stage was the highest colonized followed by the Flowering Stage with 29.9% and 24.5% for the Budding Stage was the least colonized for this site. For BUK New Site, 41% was the highest colonized for Pre-flowering Stage. This was followed by the Budding Stage with 36% and 23% was the least colonized for the Flowering Stage.

Table 1. Root length (50cm) colonization across plants and sites (Values in Parentheses are Percentages).

Plant	Site	Root Length Colonized (mm)		
		Pre-flowering	Flowering	Budding
Groundnut	A	10.48 ± 4.32^{d} (37.5)	5.92 ± 4.49^{d} (21.2)	11.52 ± 3.06^{c} (41.3)
	B	11.0 ± 3.55^{bc} (29.7)	12.56 ± 2.66^{b} (33.91)	13.48 ± 5.49^{c} (36.39)
Cowpea	A	18.00 ± 1.26^{a} (41.7)	12.40 ± 3.43^{b} (28.7)	12.76 ± 4.49^{b} (29.6)
	B	16.00 ± 2.63^{b} (36.7)	12.92 ± 4.02^{a} (29.6)	14.72 ± 3.27^{a} (33.7)
Millet	A	16.04 ± 2.54^{b} (44.6)	10.52 ± 4.60^{c} (29.3)	9.40 ± 3.63^{bc} (26.1)
	B	8.32 ± 3.92^{d} (42.8)	2.36 ± 2.50^{d} (12.6)	8.00 ± 4.49^{d} (42.8)
Sorghum	A	16.00 ± 1.68^{b} (45.6)	10.48 ± 5.02^{c} (29.9)	8.60 ± 4.13^{d} (24.5)
	B	13.88 ± 4.25^{c} (41)	7.76 ± 4.81^{bc} (23)	12.16 ± 4.87^{b} (36)

Key: A= BUK Old Site, B= BUK New Site.
Values are Mean ± SD. Means in the same column followed by different superscript letters are significantly different at $p < 0.05$ level of probability

Soil physicochemical analyses

Table 2 is showing the physicochemical parameters for Groundnut plant. The table compares for differences between the growth stages and between sites. For Pre-flowering Stage, Temperatures were taken early (around 06:30am – 07:00). Temperature difference appeared to be minute as Site A recorded 25.65℃ as against 28.75℃ for Site B. For pH, Site A recorded 5.03 while Site B recorded 5.20 which happened to be within the acidic range. In the case of Organic carbon, Site A was low with a value of 0.65% and very low for Site B with 0.33%. For Phosphorus, Site A levels were moderate as it records 15.89mg/kg as against Site B with 5.95mg/kg that falls under the low level. For Nitrogen, both sides were moderately low with 0.12%. For moisture content, Site A has higher concentration (0.40%) than Site B (0.23%). Similarly for Potassium, Site A falls in the range of low with 0.27cmol/kg as against Site B with 0.40cmol/kg which falls under the moderate range.

For the Flowering Stage, both Temperatures were favorable as Site A has 25℃ and Site B with 28℃. For pH, both sides falls under the acidic range with Site A having 5.33 and 6.19 for Site B. Both sides were low on Organic Carbon with Site A having 0.92% and 0.10%. Similarly for Phosphorus, both sides were moderately categorized as Site A records 18.82mg/kg while Site B has 15.00mg/kg. For Nitrogen however, Site A was medium level with 0.19% against Site B which was moderately high with 0.13%. For moisture content, Site B was low (0.31%) compared to Site A (0.48%). As for Potassium, Site A was moderate in content with a value of 0.34cmol/kg whilst Site B was low with 0.20cmol/kg.

At the Budding Stage, Temperature was favorable across the sites with Site A having 24.10℃ and Site B having 27.40℃. Both Sides were acidic with a pH of 6.07 for Site A and 5.83 for Site B. Site A was moderate for Organic Carbon with 1.25% and very low for Site B with 0.35%. As for Phosphorus, both sides were moderate as Site A has 17.04mg/kg and Site B with 18.93mg/kg. Site A medium levels of Nitrogen with 0.18% as against Site B which was moderately low with 0.11%. Site A was also high with moisture content (0.59%) against Site B (0.11%). Site A was low on Potassium levels with 0.30cmol/kg and Site B was very low with 0.28cmol/k.

Table 3 shows the physicochemical parameters for Cowpea. For the Pre-flowering Stage, Temperature was absolutely favorable as both sites record 27℃. Both Sides were also acidic with a pH of 5.83 and 5.94 for Sides A and B respectively. Organic carbon was high as Site A with 1.53% against Side B which was low with 0.49%. Site A had moderate amount of Phosphorus with a value of 14.49mg/kg against Site B which was low with 10.89mg/kg. Both sides were moderately high in Nitrogen content with 0.39% and 0.21% for both Sides

respectively. Site A has much moisture content (0.29%) against Site B (0.11%). Site A was high in Potassium content with 0.68cmol/kg against Site B with 0.51cmol/kg which happens to be moderate.

For the Flowering Stage, Temperature was conducive for both sites with Site A having 26℃ and 28℃ for Site B. Both sites were acidic with 5.35 and 5.45 for Sites A and B respectively. Site A was very high in Organic carbon content with 3.63% against Site B which was very low with 0.21%. Site A was low on Phosphorus with 6.90mg/kg and Site B was moderate with 5.10mg/kg. Both Sites were moderately high for Nitrogen with a record of 0.41% and 0.21% for Sites A and B respectively. In Moisture content, Site A was much with 0.29% while Site B recorded 0.11%. Site A was high with Potassium content with 0.79cmol/kg and moderate for Site B with 0.31cmol/kg.

At the Budding Stage, Temperature was also perfect for both sites with both sites recording 26℃. Similarly for pH, both sites were acidic with 5.73 and 6.33 for Sites A and B respectively. Site A was moderate for Organic carbon and low for Site A and B with 1.43% and 0.42% respectively. For Phosphorus, Site A was low and Site B moderate with values of 5.27mg/kg and 15.04mg/kg respectively. Both Sites were moderately high on Nitrogen As Site A has 0.33% and 0.41% for Site B. At this stage, moisture content for Site A was low (0.22%) while it was higher in Site B (0.39%). Similarly for Potassium, both sites were moderate with 0.58cmol/kg and 0.32cmol/kg for Sites A and B respectively.

Table 4 shows the physicochemical parameters of the Millet plant. At the Pre-flowering Stage, both sites had an optimum temperature of 26℃ and 29℃ respectively. pH appeared to be acidic at both sites also with a record of 5.61 and 5.82 respectively. For Organic carbon, Site A appeared to be moderate in concentration as against Site be which was very low with figures of 1.29% and 0.38% respectively. Phosphorus level for Site A was moderate in concentration with 9.67mg/kg with Site B recording 12.27 which is also moderate in concentration. However, for Nitrogen, Site A was moderately low with 0.14% compared to Site B which had a medium concentration of 0.18%. Site A was high in Potassium concentration with 0.61cmol/kg against 0.44 for Site B which is moderate.

For the Flowering Stage, both sites record temperatures of 26℃. pH for Site A at this stage was acidic (6.03), contrary to Site B which was rather neutral at 7.32. Organic Carbon was moderate in concentration for Site A (1.38%) as against Site B which was very low (0.12%). Phosphorus levels for both sites were moderate with 17.59mg/kg and 13.99mg/kg for Sites A and B respectively. Nitrogen level for Site A was 0.18% (moderate) while Site b was 0.14% (moderately low). Potassium for Site A was moderate (0.48cmol/kg) and low for Site B (0.28cmol/kg).

At the Budding Stage, Temperatures were normal for growth (27℃ and 26℃) for Sites A and B respectively. The soil was acidic at both sites with a pH of 6.40 and 5.07 for Sites A and B. Organic Carbon for Site A was moderate (1.32%) and very low for Site B (0.18%). Phosphorus level for Site A was 13.76mg/kg and 15.33mg/kg for Site B which both appeared to be moderate. Nitrogen for both sites was medium in concentration with Site A having 0.16% and 0.18% for Site B. Potassium concentration for Site A was moderate at this phase with 0.54cmol/kg and very low for Site B with 0.14cmol/kg. For Moisture Content, all three stages recorded a pattern of much moisture at Site A and low at Site B.

Table 5 is showing the variation in the physicochemical parameters of Sorghum. For Pre-flowering Stage, Temperature was conducive for both sites with Site A recording 26℃ and 27℃ for Site B. The pH for both sites is acidic at 5.88 and 5.21 for Sites A and B respectively. Organic Carbon for Site A was at moderate levels (1.43%) against Site B which was low (0.46%). Phosphorus content for site A was high (24.77mg/kg) while Site B was moderate (12.15mg/kg). Nitrogen level for Site A was high (0.24%) and at medium level for Site B. Potassium was high in concentration at Site A (0.70cmol/kg) and moderate for Site B (0.43cmol/kg).

At the Flowering Stage, temperature was optimum at both sites at 28℃ and 29℃ for Sites A and B respectively. Soils were acidic as both sites recorded 6.08 and 5.19 for Sites A and B respectively. Organic carbon content was high for Site A (1.64%) and very low for Site B (0.25%). Phosphorus level was moderate at Sites A and B with a record of 17.80mg/kg and 15.06mg/kg respectively. Site A has a moderately high amount of Nitrogen (0.20%) against Site B (0.17%) which is medium. Site A records moderate amount of Potassium (0.42cmol/kg) against Site B (0.20cmol/kg).

At the Budding Stage, Temperatures were optimum at 27℃ at both sites. A neutral pH at both sites (6.10 and 5.20). High amount of Organic carbon for Site A (1.63%) against Site B which was very low (0.34%). Phosphorus contents were moderate at both sites having 19.73mg/kg and 13.77mg/kg for Sites A and B respectively. Nitrogen level was moderately high at Site A (0.22%) and moderately low at Site B (0.18%). Potassium amounts were also found to be moderate at both sites, having 0.65cmol/kg and 0.34cmol/kg respectively. For Moisture Content, all three stages recorded a pattern of much moisture at Site A and low at Site B.

Table 2. Soil Physicochemical parameters for Groundnut plant.

Stage	Site	Temp (℃)	pH(H_2O)	OC (%)	P(mg/kg)	N (%)	MC (%)	K(cmol/kg)
Pre-flowering	A	25.65±0.49	5.03±0.06	0.65±0.01	15.89±0.16	0.12±0.03	0.40±0.01	0.26±0.01
	B	28.75±0.35	5.20±0.14	0.33±0.02	5.95± 0.01	0.15±0.01	0.23±0.04	0.31±0.04
Flowering	A	25.00±0.00	5.32±0.02	0.92±0.03	18.82±0.03	0.19±0.01	0.48±0.04	0.34±0.02
	B	28.00±1.41	6.19±0.05	0.10±0.00	15.00±0.01	0.13±0.03	0.31±0.01	0.20±0.01
Budding	A	24.10±1.27	6.07±0.09	1.25±0.07	17.04±0.05	0.18±0.00	0.59±0.02	0.30±0.00
	B	27.40±0.57	5.83±0.02	0.35±0.02	18.93±0.02	0.29±0.01	0.11±0.01	0.28±0.02

Keys: Keys: A= BUK Old Site, B= BUK New Site. OC = Organic carbon; P = Phosphorus; N = Nitrogen; MC = Moisture content; K = Potassium; Values are Mean±SD

Table 3. Soil Physicochemical parameters for Cowpea plant.

Stage	Site	Temp (℃)	pH(H_2O)	OC (%)	P(mg/kg)	N (%)	MC (%)	K(cmol/kg)
Pre-flowering	A	27.00±0.49	5.83±0.02	1.53±0.04	14.49±0.02	0.40±0.01	0.78±0.03	0.68±0.04
	B	27.00±0.49	5.94±0.18	0.49±0.01	10.89±0.16	0.39±0.02	0.41±0.01	0.51±0.01
Flowering	A	26.00±1.41	5.35±0.07	3.63±0.18	6.90± 0.15	0.41±0.01	0.29±0.01	0.79±0.01
	B	28.00±0.71	5.45±0.21	0.21±0.01	5.10±0.14	0.21±0.01	0.11±0.01	0.31±0.01
Budding	A	25.00±1.98	5.73±0.60	1.43±0.10	5.27±0.10	0.33±0.04	0.22±0.03	0.58±0.03
	B	27.00±1.27	6.33±0.46	0.42±0.03	15.04±0.05	0.41±0.01	0.39±0.02	0.32±0.02

Key: A= BUK Old Site, B= BUK New Site. OC = Organic carbon; P = Phosphorus; N = Nitrogen; MC = Moisture content; K = Potassium; Values are Mean±SD

Table 4. Soil Physicochemical parameters for Millet plant.

Stage	Site	Temp (℃)	pH(H_2O)	OC (%)	P(mg/kg)	N(%)	MC(%)	K(cmol/kg)
Pre-flowering	A	26.00±0.21	5.83±0.02	1.40±0.15	17.80±0.29	0.18±0.03	0.28±0.03	0.66±0.06
	B	28.00±1.91	5.71±0.14	0.44±0.08	14.00±0.01	0.19±0.01	0.19±0.01	0.47±0.04
Flowering	A	26.00±0.71	5.56±0.37	1.44±0.08	9.84±0.23	0.17±0.04	0.81±0.01	0.49±0.01
	B	27.00±0.71	5.67±0.52	0.16±0.06	12.39±0.16	0.20±0.02	0.22±0.02	0.29±0.01
Budding	A	25.00±2.69	6.74±0.83	1.41±0.13	13.88±0.17	0.19±0.01	0.78±0.03	0.52±0.03
	B	27.00±1.27	6.20±0.28	0.24±0.08	15.27±0.09	0.15±0.01	0.35±0.07	0.17±0.04

Key: A= BUK Old Site, B= BUK New Site. OC = Organic carbon; P = Phosphorus; N = Nitrogen; MC = Moisture content; K = Potassium; Values are Mean±SD.

Table 5. Soil Physicochemical Parameters for Sorghum plant.

Stage	Site	Temp (℃)	pH(H_2O)	OC (%)	P(mg/kg)	N (%)	MC (%)	K(cmol/kg)
Pre-flowering	A	26.00±0.21	5.85±0.05	1.43±0.10	24.77±0.33	0.24±0.06	0.82±0.02	0.70±0.00
	B	27.00±0.49	5.21±0.13	0.46±0.06	12.15±1.21	0.21±0.01	0.10±0.01	0.43±0.02
Flowering	A	28.00±0.71	6.08±0.11	1.64±0.20	17.80±0.29	0.20±0.02	0.75±0.08	0.42±0.03
	B	29.00±1.06	5.19±0.45	0.25±0.07	15.06±0.08	0.17±0.02	0.30±0.14	0.20±0.01
Budding	A	27.00±0.00	6.10±0.14	1.63±0.18	19.73±0.39	0.22±0.02	0.65±0.08	0.59±0.02
	B	27.00±0.71	5.20±0.28	0.34±0.06	13.77±0.33	0.18±0.04	0.34±0.08	0.26±0.08

Keys: A= BUK Old Site, B= BUK New Site. OC = Organic carbon; P = Phosphorus; N = Nitrogen; MC = Moisture content; K = Potassium; Values are Mean±SD.

Table 6. Bivariate Correlation between the Root Length Colonization and Soil Properties of the selected plants.

Soil Variables	**RLC**
Temperature (℃)	-0.369**
pH (H_2O)	0.301**
Organic Carbon (%)	0.105*
Nitrogen (%)	-0.163*
Phosphorus (mg/kg)	0.021*
Potassium (cmol/kg)	0.159*
Moisture Content (cmol/kg)	0.085*
RLC	-

Spearman's rank correlation coefficient (r) is significant at $P < 0.05$ level (2-tailed); RLC = root length colonization. ** Values showing moderate correlation. * Values showing low correlation. Degree of correlation; near ±1 = Perfect correlation: between ±0.50 and ± = High correlation: between ±0.30 and 0.49 = Moderate correlation: below ±0.29 = Low correlation.

DISCUSSION

The result of the study showed that all the plants grown on the two sites (A and B) had extensive colonization by Arbuscular mycorrhizal fungi at a time when plant growth was maximal and nutrient demand was high prior to flowering. However, it was observed that groundnut plant grown at site A and B had highest colonization by AMF at the budding phase of the plant growth. *Arachis hypogea* has thick roots with few branches which according to Baylis (1975) have greater dependence on mycorrhizal association. Isobe and Tsuboki (1998), have found higher AMF colonization in leguminous than in graminaceous crops. Thus as a legume, *A. hypogea* probably favoured mycorrhizal colonization to assist the symbioses with Rhizobium (Okon and Solomon 2014).

The AM fungal structure in the root system of the selected crops varied. Mycorrhizal structures were found in all parts of the roots. Some root parts recorded arbuscules, oval and spherical shaped vesicles were also found in this study, which was supported by Khanam *et al*. (2003, 2004).

The result of the present study showed that the pre-flowering growth phases of the selected plants had highest mycorrhizal abundance than the flowering and budding phase. This variation might be due to the differences in the structure of root system and Phosphorus uptake and also might be due to genetic variations. This result was consistent with previous findings that mycorrhizal plant community has high levels of colonization by AMF during the critical pre-flowering growth phase (Dodd *et al.* 2002; Ludwig-Müller 2010). In addition, Pringle and Bever (2008) asserted that legume plants tend to be more mycorrhizal than other plants especially during the pre-flowering stage of the plant after AM fungal inoculation. This is evident from the result of the present study where the pre-flowering phase of cowpea plants grown in site A (Table 1) had the highest mycorrhizal abundance of 18±1.26 (41.7%). Similarly, the differences in colonization and response to AMF-mediated enhancement between the leguminous (groundnut and cowpea) and cereal-grain (millet and sorghum) plants at this sites suggest that AMF may similarly promote diversity at the sites by altering the competitive balance between the more abundant legumes and cereal-grain plants.

The result on the effect of physicochemical indices on the various growth phase of groundnut plant showed that the physicochemical indices varied in different plant growth phase and sites which were supported by Howeler *et al*. (1987) who reported that the physicochemical indices varied on different factors like plant species and genera and nature of rhizosphere soil. The stimulating effects of organic carbon, comparatively higher level of N and P might have created a favourable condition for the maximum growth of the selected plants in each site. The result of the physicochemical constituents of soil samples of groundnut plant (Table 2) showed that the budding phase had higher P and N contents in the soil which resulted in higher mycorrhizal abundance of the groundnut plants in the budding phase (Table 1). Similarly, several studies reported that N and P are more significant than other nutrients for vegetative growth of plants (Akamine *et al.* 2007; Chowdhury *et al.* 2008; Hossain *et al.* 2011). This is also in line with the Study of Almagrabi and Abdelmoneim (2012) who states that the effects of *Glomus mosseae* on plant water status have been associated by enhanced host nutrition, especially phosphorus (P) nutrition. In addition, higher K, P, N, pH, OC and MC made better combination in the budding phase for better growth of groundnut plant, as compared to those in other growth phases. Other studies reported

similar effects of balanced nutrients for higher biomass production in various crops (Akamine *et al.* 2007; Hao and Papadopoulos 2004; Hossain *et al.* 2012). In contrast, the result of the physicochemical constituents of soil samples of cowpea plant (Table 3) showed that the pre-flowering phase had higher P and N contents in the soil which could have resulted in higher mycorrhizal abundance of the cowpea plants in the pre-flowering phase (Table 1). The result of the present study concurred with the findings of Sarker *et al.* (2002) and Hossain *et al.* (2012) who in their separate studies concluded that P and N are integral soil nutrients needed for plants growth. Similarly, the result of the physicochemical constituents of soil samples of cowpea plants showed that the flowering growth phase had higher moisture contents than other soils (hand feeling), which contributed to greater mycorrhizal abundance of the cowpea plants. In addition, Donald and Katherine (1999) reported that nutrient availability, absorption, and plant growth differ significantly with the physical, chemical, and biological factors of soil.

The result of the physicochemical constituents of soil samples of millet and sorghum plants (Table 4) showed that their pre-flowering phases had higher P and N contents in the soil than the flowering and budding growth phases which resulted in higher mycorrhizal abundance of the millet and sorghum plants in the pre-flowering phase (Table 1). The result of the present study indicated that soil nutrient contents especially the P and N have significantly influenced the abundance of soil microbes. In particular, the abundance of AM fungi was strongly related to soil P content. Fageria and Baligar (1997) in their study concluded that phosphorus and nitrogen are principal yield limiting factor for crop production in soils of temperate as well as tropical regions. Generally, phosphorus has positive significant interaction with N absorption and plant growth (Sumner and Farina 1986). It is commonly held view that increased growth requires more of both N and P, the inference being that mutually synergistic effects result in growth stimulation and enhanced uptake of both elements (Terman *et al.* 1977; Hossain *et al.* 2011). Results of the present study indicate that the nutrient contents of the soils played a significant role in occurrence of different species of arbuscular mycorrhizal fungi and it is evident from the perusal of the data presented in Table 6 which revealed that root length colonization positively and significantly correlated with pH (r = 0.301), organic carbon (r = 0.105), phosphorus (r = 0.021), and potassium (r = 0.159).

CONCLUSIONS

It is apparent that mycorrhizal fungi are essential components of both agricultural and native vegetation communities. Arbuscular mycorrhizal knowledge will significantly improve the survival environment of rhizosphere fungi in improving the quality of the soil and the growth of plants. The result finding concludes that there were significant associations between soil properties and root colonization. There was no conflict of interest from the findings of this research.

REFERENCES

Akamine H, Hossain MA, Ishimine Y, Yogi K, Hokama K, Iraha Y, and Aniya Y (2007). Effects of application of N, P and K alone or in combination on growth, yield and curcumin content of turmeric (*Curcuma longa* l.). *Plant Production Science, 10*, 151–154.

Almagrabi OA, and Abdelmoneim TS (2012). Using of Arbuscular mycorrhizal fungi to reduce the deficiency effect of phosphorous fertilization on maize plants (Zea mays L.). *Life Science Journal* 9 (4):1648-1654.

Baylis GTS (1975). The magnoloid mycorrhiza and mycotrophy in root systems derived from it. In: Sanders, F. E., Mosse, B. and Tinker, P. B. (eds) Endomycorrhizas. Academic Press, London. 373-389.

Brundrett MC, Bougher N, Dell B, Grove T, and Malajczuk N (1996). Working with glomalean fungi. In: Working with Mycorrhizas in Forestry and Agriculture. ACIAR Press, Canberra, Australia.

Chowdhury AHMRH, Rahman GMM, Saha BK, and Chowdhury MAH (2008). Addition of some tree leaf litters in forest soil and their effect on the growth, yield and nutrient uptake by red amaranth. *Journal of Agroforestry and Environment, 2*, 1–6.

Dodd JC, Dougall TA, Clapp JP, and Jeffries P (2002). The role of arbuscular mycorrhizal fungi in plant community establishment at Samphire Hoe, Kent, UK – the reclamation platform created during the building of the Channel tunnel between France and the UK. *Biodiversity and Conservation*, 11: 39–58.

Donald IA, and Katherine PG (1999). Better crops with plant food. *Better Crops, 83*, 1–39.

Fageria NK, and Baligar VC (1997). Phosphorus Use Efficiency by Corn Genotypes. *Journal of Plant Nutrition*, 20, 1267–1277.

Hailemariam M, and Asfaw Z (2013). Arbuscular mycorrhizal association of indigenous agroforestry tree species and their infective potential with maize in the rift valley, Ethiopia. *Agroforestry System*; Volume 87, Issue 6, pp 1261–1272.

Hao X, and Papadopoulos AP (2004). Effects of calcium and magnesium on plant growth, biomass partitioning and fruit yield of winter greenhouse tomato. *Horticulture Science*, *39*, 512–515.

Hossain MA, Akamine H, Nakamura I, and Tamaki M (2012). effects of N, P and K on growth characteristics of redflower ragleaf (*Crassocephalum crepidioides*). *Science Bulletin of the Faculty of Agriculture, University of the Ryukyus*, *59*, 13–18.

Hossain MA, Yamanishi M, Yara T, Chibana S, Akamine H, and Tamaki M (2011). Growth characteristics, yield and mineral content of redflower ragleaf (*Crassocephalum crepidioides* (Benth.) S. Moore) at different growth stages, and in dark-red soil, red soil and gray soil in Okinawa. *Science Bulletin of the Faculty of Agriculture, University of the Ryukyus*, *58*, 1–11.

Howeler RH, Sieverding E, and Saif S (1987). Practical aspects of mycorrhizal technology in some tropical crops and pastures. *Plant and Soil*, 100, 249-283.

Isobe K, and Tsuboki Y (1998). The relationship between growth promotion by arbuscular mycorrhizal fungi and root morphology and phosphorus absorption in gramineous and leguminous crops. *Japanese Journal of Crop Science*, 67, 347-352.

Khanam DARM, Solaiman M, Mridha AU, and Karim AJMS (2003). Arbuscular mycorrhizal fungi association with some agricultural crops grown in four agro-ecological zones of Bangladesh. *Bangladesh Journal of Soil Science*. 27-28: 1-12.

Khanam DARM, Solaiman M, and Mridha AU (2004). Biodiversity of arbuscular mycorrhizal fungi in agricultural crops grown under different agro ecological zones of Bangladesh. *Bulletin of Institution of Tropical Agriculture*, Kyushu University. 27: 25-33.

Lee J, Park S, and Eom A (2006). Molecular Identification of Arbuscular Mycorrhizal Fungal Spores Collected in Korea. *Mycobiology* 34(1): 7-13

Ludwig-Müller J (2010). Hormonal responses in host plants triggered by arbuscular mycorrhizal fungi, in *Arbuscular mycorrhizas: Physiology and function*. Eds. H. Koltai and Y. Kapulnik (Dordrecht: Springer), 169–190.

Okon IE, and Solomon MG (2014). Arbuscular Mycorrhizal Fungi Status of Some Crops in the Cross River Basin of Nigeria. *Global Journal of Pure and Applied Sciences*. Volume 20: 5–9

Sarker MAZ, Murayama S, Akamine H, and Nakamura I (2002). Effect of nitrogen fertilization on photosynthetic characteristics and dry matter production in F1 hybrids of rice (*Oryza sativa* l.). *Plant Production Science*, *5*, 131–138.

Scharnagl Klara. (2013). The effects of Arbuscular Mycorrhizal Fungi on Four Legume Hosts in South Florida Pine Rockland Soils. An unpublished Masters Desertation.

Sumner ME, and Farina MPW (1986). Phosphorus Interactions with Other Nutrients and Lime in Field Cropping Systems. *Advance Soil Science*, 5, 201–236.

Terman GL, Noggle JC, and Hunt CM (1977). Growth Rate-Nutrient Concentration Relationships during Early Growth of Corn as Affected by Applied N, P, and K. *Soil Science Society of America*. 41, 363–368