Response of Three Varieties of Okra (*Abelmoschus esculentus* L. Moench) to Arbuscular Mycorrhizal Fungi (*Gigaspora gigantea*) in the Humid Tropics

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Abstract

Symbiotic organisms such as arbuscular mycorrhizal fungi (AMF) are known to play important roles in sustainable agroecosystems, improving plant performance under different environmental conditions and also aid plant adaptation in the nursery. They are able to colonize the root surface, survive and multiply in microhabitats associated with the root surface and promote plant growth. The influence of AMF (Gigaspora gigantea) on growth of three varieties of Okra (Lima F1, Bassati and Local variety) was investigated in the screen house of Department of Crop and Soil Science, University of Port Harcourt. The experiment was a complete factorial combination with randomized replicates. Gigaspora gigantea was used to inoculate pots containing 10 kg of sterilized soil at 3 weeks before sowing of seeds at the rate of 0 g, 5 g, 10 g and 15 g per pot. Results showed that AMF significantly improved the growth and nutrient uptake in inoculated pot over un-inoculated pots. Pots inoculated with AMF significantly (P<0.001) increased phosphorus, nitrogen and organic carbon in post harvested soil where compared with soil before planting (BF). Stem girth and plant height were also significantly (P<0.001) higher in AMF inoculated pots when compared with the control. Pot inoculated with 10g AMF produced the optimum result while the local okra variety responded better than the other varieties. It can be concluded from the current study that the use of AMF as soil inoculants could improve okra production and the varying response of the different okra varieties to AMF emphasize the importance of fungi and plant host interactions in crop growth.

Introduction

Okra (*Abelmoschus esculentus*) (L.) Moench, is a vegetable crop belonging to the family Malvaceae. It is widely cultivated in the tropics for its young fresh leaves and fruits (Nwangburuka *et al*., 2011). Okra is regarded as a popular health food as it has high fiber, vitamin C and folate contents (Corleone, 2014). Its production in Nigeria either sole or in crop mixture has increased due to its high nutritional value. (Olawuyi et al, 2012).

However, some of the major constraints identified to be responsible for low production of these crops include poor soil fertility, high cost and unavailability of inorganic fertilizer, difficulty in obtaining adequate amount for large scale agriculture and delay in the release of the essential mineral nutrients for immediate use by the plant (Olawuyi et al., 2010). The use of inorganic fertilizers in most soils of the tropics has been reported to be accompanied by soil acidity problems (Kang *et al*., 1990). Alternative to the use of organo-mineral fertilizer which is environmental friendly, readily available and cheap for a common farmer have been advocated. This suggests the use of arbuscular mycorrhizal fungi (AMF), which are commonly available.

Symbiotic associations between AMF and plant roots are widespread in the natural environment and can provide a range of benefits to the host plant (Gosling et al., 2005). Mycorrhizal fungi contribute to overcoming mineral element deficiencies, improve plant ability to use the soil resources and improve plant performance (Abbott and Robson, 2006).
Although some studies have been done elsewhere to evaluate the effect of AMF on the growth and yield of okra, no such studies has been documented on comparative evaluation of AMF on different varieties of okra. Thus the objective of this study was to investigate the effect AMF (*Gigaspora gigantea*) applied at four levels on three varieties of okra commonly cultivated in the humid tropic of southern, Nigeria.

Materials and Methods

The experiment was conducted at the screen house, Department of Crop and Soil Science, University of Port Harcourt. The farm is situated at latitude 6° 45 N to 7° E with an average temperature of 27°C, relative humidity of 78% and an average rainfall ranging of 2500-4000mm (Nwankwo and Ehirim 2010). Samples of top soil (0 to 30cm depth) were taken randomly from the experimental farm, air-dried, sieved through a 2 mm sieve and analyzed for their physical and chemical properties using standard procedures as described by Udo et al (2009) before use. The treatments consisted of four levels (0, 5, 10, 15 g/plant) of AMF (G*igaspora gigantean).* The mycorrhizal fungi; *Gigaspora gigantea* were multiplied for increase using available inocula source collected from the Department of Soil Science, University of Calabar, Nigeria. This consists of mixture of chopped root of the trapping plant hyphae, spores and soil fragments. Seeds of Okra varieties (Bassati, Lima F_1 and Local variety) were obtained from Agro Tropic Industries, Port Harcourt Nigeria. The choice of varieties used was based on the availability and acceptability. The variability of seeds was tested using the floatation method. They were planted in 10litre plastic pots filled with sterilized soil (4 seeds per pots) at a depth of about 2.5cm below the soil surface, and later thinned to 2 seedlings per pot 2 week after germination. The pots were watered when necessary. Growth parameters such as stem girth, number of leaves and plant height were assessed. Data were collected at 2, 4, 6 and 8WAI. Soil samples were taken for post-harvest analysis to ascertain its nutrients contents. The experiment was laid out in a completely randomized design (CRD) with three replicate. Data was subjected to Analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) was used to test for significant different between means at 5% probability level.

Results and Discussion

Arbuscular mycorrhizal fungi improved the soil total nitrogen, calcium and available phosphorous content of the soil, this can be observed in the increase in total nitrogen, calcium and available phosphorous content of inoculated soils analysed after the experiment. The physical analysis of the soil used for this experiment revealed that it contained mean value of 90% sand, 6.24% clay and 3.76% silt. The soil pH was fairly acidic with pH value of 6.0. It was observed that the AMF inoculated soil had higher total organic carbon, total nitrogen and calcium in post harvested soil than in soil BP. (Table 1 & 2)

Table 1: Physico-chemical properties of soil before treatment with AMF

pH	Sand %	Silt %	Clay %	TOC %	TN %	Avail.P (mg/kg)	Ca (Cmol/kg)	Mg (Cmol/kg)	K (Cmol/kg)	Na (Cmol/kg)
6.0	92.0	2.0	6.0	0.86	0.025	33.34	0.78	1.34	0.792	0.81

TOC = total organic carbon, TN=total nitrogen, Available P=available phosphorus, Ca=calcium, Mg=magnesium, K=potassium, Na=sodium

Table 2: Physico-chemical properties of soil after treatment with AMF

AMF/Soil Properties(g)	pH	Sand %	Silt %	Clay %	TOC %	T N %	Avail.P (mg/kg)	Ca (Cmol/kg)	Mg (Cmol/kg)	K (Cmol/kg)	Na (Cmol/kg)
0	5.8	88.0	8.6	3.4	2.89	0.16	30.10	0.64	1.48	1.74	0.72
5	6.0	89.2	7.0	3.8	1.95	0.75	96.7	1.02	0.89	0.28	0.33
10	5.9	93.2	4.0	2.8	2.34	0.82	139.3	0.96	0.46	0.28	0.48
15	6.1	85.2	12.0	2.8	2.15	0.69	116.7	1.00	0.61	0.16	0.52

TOC = total organic carbon, TN=total nitrogen, Available P=available phosphorus, Ca=calcium, Mg=magnesium, K=potassium, Na=sodium, AMF= arbuscular mycorrhiza fungi (treatment)

The available P in the post harvested soil increased astronomically more than that of soil BP. 10g AMF had highest avail P, 139.3mg/kg; 15g AMF, 116.7mgkg while 5g AMF had the lowest value of 96mg/kg; against 33.34mgkg value on soil BP. On the other hand, the control had lower value 30.10 mg/kg than that of soil BP. The increase in available phosphorus and calcium content of the soil analysed after the experiment confirm the work of Hamel and Strullu, (2006), who reported that plants directly influence soils in their quality as the main source of metabolically activity and soil organic matter. AMF play an important role in phosphorous mobilization in soils having a relatively low level of available phosphorous. Plants also modify the soil environment, as they are the determinant of the AMF networks development and thus, their influence in soil.

The TN content of the post-harvested soil was higher than that of soil BP. However 10g AMF had the highest value of 0.82%. This may have resulted from the mutualistic interaction that exists between mycorrhizal and rhizobia which led to increased number of nodules formation and nitrogen fixation (Hodge, 2003). This implies that the application of AMF beyond 10g/10kg soil may not be of economic value.
The Bassati treated with 15g of AMF after 2WAI recorded the highest plant height (19.42cm) which did not differ from 10g AMF inoculation for Bassati (18.50cm), 15g of AMF in Lima F_1 (18.32cm) and 15g AMF in local variety (18.82cm) but different from the control pots in all the varieties. However the local variety treated with 15g after 8WAI produced highest plant height (37.76cm) which is significantly ($P>0.05$) different from other treatment (Table 2).
There was no significant difference ($P>0.05$) in stem girth between treatments at 4weeks after inoculation for all the varieties (Table 3). The local variety showed the highest plant height at 15g AMF (3.83cm) inoculation which was not significantly different from Bassati and Lima F_1.

The number of leaves in inoculated plant at 2WAI is significantly higher than the control in Bassati and Lima F_1 varieties; this observation remains constant for the entire period of the experiment. However, Lima F_1 (5.33cm) and local variety (5.33cm) treated with 15g of AMF produced the highest number of leaves which was better than the control (Table 4).
Generally, from the findings of this study, plant growth parameters were significantly affected by the inoculation of AMF. The increase in stem height, stem girth, leaf area and leaf number of inoculated plants compared to un-inoculated plants in all the varieties is consistent with the findings of El-Shaikh and Mohammed (2009) who reported that AMF increased the growth parameters of okra. This is possibly due to the enhanced nutrient absorption caused by the arbuscular mycorrhizal whose extra-radical hyphae may have increased root absorbing

surface area leading to more nutrient absorption for enhanced growth. The inoculation with AMF has been shown to increase chlorophyll content of leaves (Tanwar *et al*., 2013). Thus, increased chlorophyll would have resulted in increased photosynthesis and subsequently increased biomass production and accumulation, this supported the view of Olawuyi et al. (2010) and Schippers, (2000) which reported the contribution of nitrogen sources in promoting the vegetative portion of the plant, producing large green leaves, and also necessary for dropping of fruits. There was a significant increase in plant height and stem girth between inoculated plants and uninoculated plants in all the varieties as observed in the present study. Meena and Dixit (2008) reported that Vescicular Arbuscular Mycorrhiza (VAM) + *Azatobactor* inoculation increased the plant height in okra cultivar Arka Anamika. According to Hamel (2003), inoculation of AMF contributes positively to growth and development of plant.

Table 3: Effect of AMF Inoculation on Stem Height of Three Okra Varieties.

Varieties	AMF(g)	2WAI	4WAI	6WAI	8WAI
Bassati	0	9.36^{de}	12.29^{e}	18.26^{d}	25.66^{f}
	5	15.32^{c}	18.00^{d}	25.40^{c}	30.63^{d}
	10	18.50^{ab}	21.45^{ab}	27.42^{bc}	33.60^{c}
	15	19.42^{a}	21.58^{ab}	30.80^{a}	34.43^{c}
Lima F_1	0	8.00^{e}	10.58^{e}	15.02^{e}	20.53^{h}
	5	14.12^{c}	19.46^{b-d}	20.86^{d}	23.83^{g}
	10	17.40^{b}	21.75^{ab}	24.43^{c}	27.53^{e}
	15	18.32^{ab}	22.82^{a}	25.20^{c}	27.93^{e}
Local Variety	0	10.52^{d}	12.18^{e}	20.16^{d}	27.24^{e}
	5	13.81^{c}	18.35^{cd}	25.46^{c}	33.33^{c}
	10	17.41^{b}	20.42^{a-d}	29.26^{ab}	36.00^{b}
	15	18.83^{ab}	20.03^{a-d}	31.13^{a}	37.76^{a}

Means with different superscript on the same row are significantly different from each other ($p<0.05$) according to the Duncan multiple range test., AMF= Arbuscular mycorrhizal fungi, WAI=weeks after inoculation.

Table 4: Effect of AMF Inoculation on Stem Girth of Three Okra Varieties.

Varieties	AMF (g)	2WAI	4WAI	6WAI	8WAI
BASSATI	0	0.82^{d}	0.90^{b}	1.43^{de}	1.71^{e}
	5	1.70^{bc}	1.87^{a}	2.10^{c-e}	3.26^{b}
	10	1.80^{bc}	2.23^{a}	2.23^{c-e}	2.50^{d}
	15	1.82^{ab}	2.20^{a}	2.53^{a-d}	2.66^{cd}
LIMA F1	0	0.61^{e}	0.74^{b}	1.30^{e}	1.43^{e}
	5	1.62^{c}	2.13^{a}	2.31^{c-e}	3.13^{bc}
	10	1.85^{ab}	2.09^{a}	2.45^{a-e}	3.33^{b}

	15	1.83[ab]	2.16[a]	2.43[b-e]	3.00[bc]
LOCAL VARIETY	0	0.81[d]	0.83[b]	1.56[de]	1.90[e]
	5	1.72[bc]	2.00[a]	3.20[a-c]	3.33[ab]
	10	1.85[ab]	1.92[a]	3.50[a]	3.46[ab]
	15	1.98[a]	2.32[a]	3.60[ab]	3.83[a]

Means with different superscript on the same row are significantly different from each other ($p<0.05$) according to the Duncan multiple range test., AMF= Arbuscular mycorrhizal fungi, WAI=weeks after inoculation.

Table 5: Effect of AMF Inoculation on Number of Leaves of Three Okra Varieties.

Varieties	AMF (g)	2WAI	4WAI	6WAI	8WAI
Bassati	0	1.67b	1.67[b]	1.67[b]	1.67[b]
	5	4.00[a]	4.00[a]	4.00[a]	4.00[a]
	10	4.67[a]	4.67[a]	4.67[a]	4.67[a]
	15	5.00[a]	5.00[a]	5.00[a]	5.00[a]
Lima F_1	0	2.33[b]	2.33[b]	2.33[b]	2.33[b]
	5	4.00[a]	4.00[a]	4.00[a]	4.00[a]
	10	5.00[a]	5.00[a]	5.00[a]	5.00[a]
	15	5.33[a]	5.33[a]	5.33[a]	5.33[a]
Local Variety	0	2.33[a]	2.33[a]	2.33[a]	2.33[a]
	5	4.33[a]	4.33[a]	4.33[a]	4.33[a]
	10	5.00[a]	5.00[a]	5.00[a]	5.00[a]
	15	5.33[a]	5.33[a]	5.33[a]	5.33[a]

Means with different superscript on the same row are significantly different from each other ($p<0.05$) according to the Duncan multiple range test., AMF= Arbuscular mycorrhizal fungi, WAI=weeks after inoculation.

Conclusion

It can be concluded that AMF helps in mineralization of nutrient thereby making them available for plant absorption and utilization. The AMF significantly improved soil nutrient status as observed in the growth of okra. On the average, cumulative growth response of plants inoculated with 10g and 15g AMF gave the best results. Thus, it is economically wise to use 10g AMF. Based on comparative evaluation of the three okra varieties used, Local varieties outperformed Bassati and Lima F_1 and this could be because of the easy adaptation of the Local variety to Indigenous AMF than the hybrid varieties.

Therefore, Local variety is the relative host of AMF and could be used to improve the growth of the okra and also multiply the indigenous AMF under prevailing soil conditions. The farmers should be encouraged to use AMF as it is environmentally friendly, required no specialised skill for its application and there is no need of frequent application as it is in the case of chemical fertilizers.

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