EFFECTS OF DIFFERENT SOIL AMENDMENTS ON THE GROWTH 
AND YIELD OF OKRA IN A TROPICAL RAINFOREST 
OF SOUTHWESTERN NIGERIA 

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Abstract: This study investigated the effects of different soil enhancers on the 
growth response of okra \textit{[Abelmoschus esculentus (L.) Moench]} cultivated on a 
‘contaminated’ field with sewage sludge from the two oxidation ponds of the 
Obafemi Awolowo University (OAU), Ile-Ife, Nigeria. This was with a view to 
assessing the growth performance and yield of the test crop under different soil 
amendments. Okra variety, NHAe 47-4 with NPK 12-12-17 (IO), compost organic 
fertilizer (OR), \textit{Glomus mosseae} mycorrhiza (MY) and zero fertilizer applications 
as control (CT) was laid out in a completely randomised block design and each 
treatment plot (4 x 2 m) was replicated four times. Selected weather parameters 
were collected from a meteorological station in OAU campus during the period of 
the experiments. Growth parameters such as plant height, stem girth and number of 
leaves of okra increased with added soil amendments from four weeks after 
planting in the order: IO > OR > MY > CT. In 2010, the highest mean yield of 16.3 
t ha\(^{-1}\) obtained with 6.0 t ha\(^{-1}\) of MY was not significantly higher than 15.4 t ha\(^{-1}\) 
obtained with application of 0.2 t ha\(^{-1}\) of IO, but significantly \((p < 0.05)\) higher than 
13.1 and 10.4 t ha\(^{-1}\) obtained with applications of 6.0 and zero t ha\(^{-1}\) of OR and CT 
respectively. Comparative okra yield, though relatively higher with mycorrhizal 
inoculation, but lower with no soil amendment was obtained in 2011. The study 
concluded that a direct linear relationship existed between solar radiation and okra 
productivity. Also, for a moderately ‘treated field’ with sewage sludge from 
domestic wastes, arbuscular mycorrhizal fungi can be integrated into soil fertility 
management to achieve low-cost sustainable agricultural systems for enhanced 
productivity of okra. 

Key words: arbuscular mycorrhizal fungi, okra yield, sewage sludge, soil 
fertility, solar radiation, organic farming. 

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Introduction

Improved soil fertility through the application of fertilizers is an essential factor that enables the world to feed the billions of people that are added to its population (Brady and Weil, 1999). Increasing population and the consequent increased demand for food production and food quality in Nigeria require that proposed agronomic strategies for improvement should in general avoid high input costs. Despite the inherent low fertility status of the soils in Nigeria, carbon farming has not been well understood. Obi et al. (2005) reported that okra [Abelmoschus esculentus (L.) Moench] yield and yield components were lower without the application of NPK, and that with increase in rate of NPK application, yield of okra increased. The use of inorganic fertilizers alone has not been helpful under intensive agriculture because they aggravate soil degradation (Sharma and Mittra, 1991).

The soil degradation is brought about by loss of organic matter which consequently results in soil acidity, nutrient imbalance and low crop yields. The restoration and rehabilitation of degraded soils for high crop productivity using off-farm organic wastes such as sewage sludge, crop wastes, domestic and municipal wastes could help to restore the lost organic matter sustainably. The importance of organic manure and mineral fertilizer in tropical agriculture for increased world food production cannot be over-emphasized. The need to minimize the dependence on chemical fertilizers and to encourage the use of bio-fertilizers on a large scale in farming communities has been proposed as diagnostic condition for soil health and high crop productivity (Parr and Hornick, 1992).

Also, the levels of mycorrhizal colonization were greater under organic treatments than under the conventional practices (Kafkafi et al., 1988). Increase in soil organic matter has been found to enhance the available phosphorus in the soil through the organic anion, thus preventing P fixation and replacing the P bound to the soil (Nagarajak et al., 1970). Maintenance and improvement of soil quality are vital if agricultural productivity and environmental quality are to be sustained for future generations (Reeves, 1997). Arbuscular mycorrhizal fungi (AMF) can be integrated into soil management to achieve low-cost sustainable agricultural systems (Hooker and Black, 1995). AMF improve plant-water relations and thus increase the drought resistance of host plants (Nelsen, 1987), improve disease control (Khan, 2006) and increase mineral uptake and yield of crop (Adewole et al., 2010), hence, reduce the use of fertilizers. Mycorrhiza is undoubtedly of extraordinary importance in plant production, plant and soil ecology and plays a key role in sustainable agriculture (Bethlenfalvay et al., 1998).

Despite the importance of bio-fertilizers, such as compost organic fertilizer and Glomus mosseae for improved crop yield, there is a dearth of information on these soil enhancers when okra is cultivated in an Alfisol sewage sludge-treated
soil of the tropical rain forest. This study was therefore aimed at investigating the influence of weather variation and different soil amendments on the growth and yield of okra in a sewage sludge-treated soil.

Material and Methods

Study area, experimental design and agronomic details

The study was conducted on an Alfisol farmland (07°30.362’N and 004°30.747’E) around the oxidation ponds of the Obafemi Awolowo University (OAU), Ile-Ife, Nigeria during the wet season of 2010. The study area falls within the tropical rain forest of south-western Nigeria. Viable seeds of okra variety, NHAe 47-4 were purchased from National Horticultural Research Institute, Ibadan, Nigeria. The ‘minimally contaminated’ experimental site with treated sewage sludge was manually cleared with hand hoe and cutlass two times at two weeks interval. The sewage sludge was a product of domestic/kitchen wastes, majorly from the students’ hostels and the staff quarters of the OAU channelled into the two oxidation ponds. These wastes were allowed to undergo oxidation inside the ponds before dislodgement to the open land near the ponds by the university authority.

Using random sampling technique, three surface (0-15 cm depth) soil samples were collected with soil auger from the cleared farmland. The pre-planting soil samples were air-dried for 7 days, sieved through a 2-mm mesh and analysed for soil physical and chemical properties using standard methods. The mean values of selected soil properties before planting in 2010 and 2011 are presented in Table 1. The experiment consisted of four, 19 x 2 m blocks; each block was in turn divided into four plots of 4 x 2 m with an alley of 0.5 m between blocks and 0.5 m within plots; laid out in a completely randomised block design with four treatments and each treatment was replicated four times. The treatments consisted of 6.0 t ha⁻¹ organic fertilizer (OR); 0.2 t ha⁻¹ NPK 12-12-17 (IO); 6.0 t ha⁻¹ of *Glomus mosseae* mycorrhiza (MY) and zero soil amendment as control (CT). The NPK and organic fertilizers were purchased at a local market. The mycorrhiza used was an inoculum of soil containing spores, hyphae and maize roots infected with *Glomus mosseae*.

Sowing was done with four seeds per hole using 0.6 x 0.3 m planting distance. The soil amendments were applied at sowing. The okra seedlings were thinned to two stands per hole at two weeks after planting (WAP) to give plant population of 111,111 plants per ha. Three manual weeding treatments of the plots were carried out at 2, 5 and 7 WAP using hand hoe. Collection of data on growth parameters such as stem girth, number of leaves, and plant height of okra commenced at 2 WAP and thereafter, continued weekly. Harvesting of okra pods began 45 days after planting and continued until 15 WAP, when the experiment was terminated.
At each time of harvest, the pods were counted per plot to get the number of pod and weighed to get the fresh pod weight. A repeat experiment was conducted on the same plot of land during the wet season of 2011.

Table 1. Selected physical and chemical properties of experimental site before planting (2010-2011).

<table>
<thead>
<tr>
<th>Soil property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH value (1:2 Soil - 1 M CaCl₂)</td>
<td>5.00</td>
</tr>
<tr>
<td>Organic carbon (g kg⁻¹)</td>
<td>9.92</td>
</tr>
<tr>
<td>Total nitrogen (g kg⁻¹)</td>
<td>3.85</td>
</tr>
<tr>
<td>Available phosphorus (mg kg⁻¹)</td>
<td>74.25</td>
</tr>
<tr>
<td>CEC (cmol kg⁻¹)</td>
<td>11.59</td>
</tr>
<tr>
<td>Exchangeable acidity (cmol kg⁻¹)</td>
<td>2.90</td>
</tr>
<tr>
<td>Heavy metals (mg kg⁻¹)</td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>0.01</td>
</tr>
<tr>
<td>Pb</td>
<td>0.45</td>
</tr>
<tr>
<td>Cu</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Source: Adapted from Adewole and Ilesanmi (2011).

The soil pH was electrometrically determined (McLean, 1982). Nitrogen was determined by Kjeldahl method (Bremner and Mulvaney, 1982), available phosphorus was determined using Bray P1 method (Olsen and Sommers, 1982). Exchangeable cations (K⁺, Na⁺, Ca²⁺ and Mg²⁺) were extracted with 1 M ammonium acetate and the concentrations of Ca²⁺ and Mg²⁺ in the soil extracts were read using Perkin-Elmer Model 403 (Shelton, Connecticut, USA) Atomic absorption spectrophotometer (AAS) while K⁺ and Na⁺ were read on Gallenkamp flame photometer (Thomas, 1982). The concentrations of Cu, Pb and Cd in the soil extracts were read on AAS.

Chemical composition of compost organic fertilizer used

Nitrogen was determined by Kjeldahl method (Bremner and Mulvaney, 1982). Available phosphorus was determined using Bray P1 method (Olsen and Sommers, 1982). Calcium ions, Mg²⁺ and K⁺ were extracted using 1 M ammonium acetate buffered at pH 7.0 as extractant (Thomas, 1982) and the concentrations of Ca²⁺ and Mg²⁺ in the compost extracts were read using AAS, while K⁺ was read on flame photometer. The chemical composition of compost organic fertilizer was: N 6.4%, P 6.4%, K 4.6%, Ca 12.4% and Mg 5.9%.
Selected weather parameters

The selected monthly mean weather data (surface soil temperature, rainfall, relative humidity and solar radiation) collected from the Space Applications and Environmental Science Laboratory, OAU, Ile-Ife, Nigeria during the cropping periods in 2010 and 2011 are presented in Table 2.

Table 2. Selected monthly mean weather parameters (2010-2011).

<table>
<thead>
<tr>
<th>Month</th>
<th>Soil surface temperature (°C)</th>
<th>Rainfall (mm)</th>
<th>Relative humidity (%)</th>
<th>Solar radiation (Wm(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>25.8</td>
<td>25.2</td>
<td>142.9</td>
<td>265.4</td>
</tr>
<tr>
<td>May</td>
<td>24.0</td>
<td>27.0</td>
<td>190.8</td>
<td>105.1</td>
</tr>
<tr>
<td>June</td>
<td>23.5</td>
<td>24.9</td>
<td>127.4</td>
<td>175.4</td>
</tr>
<tr>
<td>July</td>
<td>23.2</td>
<td>24.9</td>
<td>152.2</td>
<td>298.6</td>
</tr>
<tr>
<td>August</td>
<td>23.7</td>
<td>24.5</td>
<td>201.6</td>
<td>173.8</td>
</tr>
<tr>
<td>September</td>
<td>23.9</td>
<td>24.0</td>
<td>269.0</td>
<td>292.7</td>
</tr>
</tbody>
</table>

Statistical Analysis

The data obtained were subjected to descriptive and one-way analyses of variance to test for their treatment effect. Test of significance for differences in means was statistically compared using Duncan’s multiple range tests at 5% level of probability.

Results and Discussion

Physical and chemical characteristics of soil

The mean soil pH (1 : 2 Soil - 1 M CaCl\(_2\)) was 5.00 indicating acidic soil conditions. Some of the other mean values obtained were: organic carbon 9.92 g kg\(^{-1}\); total nitrogen 3.85 g kg\(^{-1}\); and CEC 11.59 cmol kg\(^{-1}\) which were considered moderate for okra cultivation in Nigeria (Olaniyi et al., 2010).

Plant height of okra

Figure 1 shows the effects of the soil amendments on plant height of the okra plants.
At 4 WAP, the plant height had significantly (p < 0.05) lowest values in plots with OR and CT fertilizer applications than in IO and MY treatments. However, from 6 WAP, only plants in the CT had significantly (p < 0.05) lowest height. The N and P in the inorganic fertilizer were easily absorbed by the okra plants which would have enhanced the rapid plant growth. Also, the ability of added arbuscular mycorrhiza prevented the native P from being fixed, but enhanced P availability could have been responsible for okra rapid growth (Sharma and Mittra, 1991). The absorption of mineralized OR became manifested from 6 WAP. The order of increase in okra plant height was IO > OR > MY > CT until 8 WAP. However, from 10 WAP, plots with OR were leading, probably because the organic fertilizer used had just fully mineralised for the okra plants to use.

Stem girth of okra

A similar trend recorded in the height of okra plants was obtained in stem girth from 2 to 12 WAP (Figure 2). At 4 WAP, the stem girth was significantly (p < 0.05) highest in plots with IO fertilizer application than in other treatments, but not significantly (p < 0.05) different from 6 WAP, except for the CT treatment.
Figure 2. Mean stem girth (cm) under different soil amendments (2010-2011).

Legend: MY = Mycorrhiza; IO = Inorganic Fertilizer; OR = Organic Fertilizer; CT = Control.
Bars indicate level of significance at $p < 0.05$.

Number of leaves of okra

From 8 WAP, the number of leaves was significantly ($p < 0.05$) highest in plots with IO fertilizer application than in other treatments (Figure 3).

Figure 3. Mean number of leaves under different soil amendments (2010-2011).

Legend: MY = Mycorrhiza; IO = Inorganic Fertilizer; OR = Organic Fertilizer; CT = Control.
Bars indicate level of significance at $p < 0.05$. 
Except for IO, gradual decrease was observed at 12 WAP due to shedding of leaves in the other treatments. Plants in the control plots did not perform too well in terms of growth as they had to rely only on the native soil nutrients.

Yield of okra

In 2010, the highest okra mean yield of 16.3 t ha$^{-1}$ obtained with mycorrhizal inoculation was not significantly higher than 15.4 t ha$^{-1}$ obtained with application of inorganic fertilizer, but significantly (p < 0.05) higher than 13.1 t ha$^{-1}$ obtained with application of organic fertilizer and 10.4 t ha$^{-1}$ obtained when no soil amendment was applied (Table 3). Ryan and Angus (2003) earlier obtained improved biomass, plant growth and yield of okra with AMF applications.

Table 3. Mean yield (t ha$^{-1}$) of okra pods (2010-2011).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mycorrhiza</td>
<td>16.3a</td>
<td>17.9a</td>
</tr>
<tr>
<td>Inorganic Fertilizer</td>
<td>15.4ab</td>
<td>15.6b</td>
</tr>
<tr>
<td>Organic Fertilizer</td>
<td>13.1b</td>
<td>15.2b</td>
</tr>
<tr>
<td>Control</td>
<td>10.4c</td>
<td>7.6c</td>
</tr>
</tbody>
</table>

Means followed by the same letter(s) within a column are not significantly different at p < 0.05 by Duncan’s Multiple Range Test.

Comparative okra yield, though relatively higher with mycorrhizal inoculation, but lower with no soil amendment was obtained in 2011. The residual effects from the previous soil amendments with the new additions could account for these differences. The control plots depended only on the native soil fertility; hence the lower okra yield obtained during the second cultivation was not out of place. *Glomus mosseae* (an arbuscular mycorrhiza) proved most effective for good growth performance and yield of okra. Previous studies of Shaheen et al. (2007), and El-Shaikh and Mohammed (2009) showed an increase in agronomic growth performance and yield of okra when bio-inoculants were applied to soil. The roots of plant that developed well and had enhanced access to soil nutrients when soils are treated with arbuscular mycorrhiza (Adewole et al., 2010) could be attributable to increased okra yield.

Typical tropical weather conditions are highly variable (Nathaniel, 2011). The weather parameters measured in 2010 and 2011 were greatly different, thus confirming the high variability of weather conditions of the study area, a typical tropical environment. The solar radiation is a function of radiation use efficiency and this actively participates in the process of photosynthesis and it has a linear relationship to crop productivity (Kumar et al., 2008). In 2011, with the exception
of April, the monthly mean solar radiation measured during other months was higher than their corresponding months in 2010. This may have accounted for higher okra yields in 2011 for all the treatments, except for the control plots whose low native soil nutrients might have been the major contributing factor to low yield of okra.

**Conclusion**

The mean yield of okra (t ha⁻¹) was in the order: MY > IO > OR > CT, suggesting that treated sewage sludge, in combination with *Glomus mosseae* can be integrated into the soil fertility management. We therefore conclude that for a moderately ‘contaminated field’ with treated sewage sludge from domestic wastes, arbuscular mycorrhizal fungi can be integrated into soil fertility management of the humid tropics to achieve low-cost sustainable agricultural systems for enhanced productivity of okra. Also, higher solar radiation enhanced the yield of okra.

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**References**


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Effects of soil amendments on the growth and yield of okra

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R e z i m e

U ovom istraživanju su ispitivani efekti različitih tretmana zemljišta na rast bamije \([Abelmoschus esculentus\) (L.) Moench] uzgajane na polju „zagadenom” kanalizacionim muljem iz dva oksidaciona jezera Obafemi Avolovo Univerziteta (OAU), Ile-Ife u Nigeriji. Cilj je bio da se proceni rast i prinos ispitivanog useva pri različitim popravkama zemljišta. Sorta bamije, NHa 47-4 je ispitivana sa četiri različita tretmana zemljišta: NPK 12-12-17 (IO), kompostno organsko đubrivo (OR), mikoriza \(Glomus mosseae\) (MY) i bez primene đubriva kao kontrole (CT). Ogled je postavljen po potpuno slučajnom blok sistemu sa četiri ponavljanja (parcele 4 x 2 m). Odabrani vremenski parametri su bili prikupljeni sa meteorološke stanice u OAU kampusu tokom eksperimenata. Parametri rasta kao što su visina biljke, obim stabljike i broj listova bamije su se povećavali sa tretmanima zemljišta od 4. nedelje posle setve po sledećem redosledu: IO > OR > MY > CT. U 2010. godini, najviši prosečni prinos od 16,3 t ha\(^{-1}\) postignut sa 6,0 t ha\(^{-1}\) MY nije bio značajno viši od 15,4 t ha\(^{-1}\) postignutog primenom 0,2 t ha\(^{-1}\) IO, ali je bio značajno (p < 0.05) viši od 13,1 i 10,4 t ha\(^{-1}\) postignutih primenom 6,0 i nula t ha\(^{-1}\) u varijantama OR, odnosno CT. U 2011. godini je bio postignut relativno viši prinos bamije mikoriznom inokulacijom, ali niži bez popravke zemljišta. Istraživanje je pokazalo da postoji direktna linearna veza između sunčevog zračenja i produktivnosti bamije. Takođe, za umereno „tretirana polja” kanalizacionim muljem iz domaćih otpada, arbuskularno-mikorizne gljive mogu biti korišćene za popravku plodnosti zemljišta kako bi se postigli jeftini održivi poljoprivredni sistemi za povećanu produktivnost bamije.

Ključne reči: arbuskularno-mikorizne gljive, prinos bamije, kanalizacioni mulj, plodnost zemljišta, sunčevo zračenje, organska poljoprivreda.

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