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Investigation of Mulching Materials and Soil Amendment Effect on the Growth and Yield of Okra (*Abelmoschus esculentus*)

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ABSTRACT

A study was carried out in pots at the Teaching and Research Farm of the Faculty of Agriculture, University of Abuja to assess the effects of different mulching materials and soil amendments on the growth and yield of okra. The experiment factors were soil amendment with three levels (inorganic fertilizer application, mycorrhizal inoculants and no-amendment) and mulch with four levels (leguminous live mulch, plastic, wood shaving and no-mulch). Inorganic fertilizer source was NPK 15:15:15 while the mycorrhizal inoculant contained Glomus mosseae. The experimental setup was a completely randomized design with three replicates. Number of leaves at harvest, plant height (cm), shoot weight (g), root length (cm) were significantly ($p \leq 0.05$) affected by the mulch types. Soil amendments significantly ($P \leq 0.05$) influenced the pod weight (g) and number at harvest, number of leaves, plant height (cm), fresh and dry weights (g) of shoot and root. Mulch type and soil amendment interaction effects were highly significant on pod weight (g) at harvest, number of branches, root length (cm) and shoot dry weight (g). The best performance in terms of root length occurred under plastic mulch (53.78 cm) which was, however, not significantly different from the performance under legume mulch (53.03 cm).

Key words: Mulches, Mycorrhizal inoculation, Okra, Inorganic fertilizer

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench] is an important tropical annual herb and vegetable crop which plays a vital role in human diet. In fact, okra contains carbohydrate, proteins and vitamin C in considerable quantities (Adeboye and Oputa, 1996). Its cultivation has been widely practiced because of its importance to economic development. Thus, world okra production is estimated at 6 million tons per year with an increasing total cultivation area over the years. Nigeria is the second world largest producer after India (Ngbede *et al*., 2014).

In Nigeria, okra is widely consumed either in fresh (usually boiled, sliced or fried) or in dried form (Fatokun and Chedda, 1983). Its high nutritional importance has aroused small-scale farmers' interest in commercial cultivation for income generation and other opportunities (Selleck and Opena, 1985). In spite of this awareness, its optimum yields of 2 - 3 t ha^{-1} has not been attained in the tropical countries partly because of a continued decline in soil fertility. Nevertheless, the physical, chemical or biological properties of soils could be enhanced with application of organic or inorganic materials such as fertilizer, organic manure or biofertilizer, which could improve okra production. However, the use of inorganic fertilizers as soil amendment by smallholder farmers is limited by their poor financial resources.

Consequently, due to the unaffordability of inorganic fertilizers, the use of organic fertilizers remains the most exploitable natural resources for smallholder farmers, as cheap nutrients sources. Mulches are materials used to cover soil surface to conserve water, improve temperature, suppress weed and add to its productivity (Bhardwaj, 2013). Organic mulch is of plant and animal origin including straw, leaves, manure, sawdust, wood shavings and grass while inorganic mulch includes plastic film, sand and stone. Mulching is known to increase yield and improve product quality through its favorable effects on the physical, chemical, and biological properties of the soil and as well enhances root development leading to improved crop performance and yield (Parmar and Sharma, 1996; Hochmuth *et al*., 2001; Anikwe *et al*., 2007; Sarolia and Bhardwaj, 2012).

As well, the improvement of plant nutrients absorption through mycorrhizae symbiosis constitutes an affordable way for smallholder farmers. Arbuscular mycorrhizal fungi (AMF) symbiosis with plant roots enhances crop growth and yield through increased nutrient and water uptake, as well as alteration of some physiological processes in the plants (Douds *et al*., 2005).

Organic matter has also been noted to positively influence AMF proliferation (Vaidya *et al*., 2008). High biomass yield of cassava has been attributed to a positive synergistic effect of AMF and mulching (Iniobong *et al*., 2010). In addition, these practices contribute to the sustainability of soil productivity. Considering the beneficial aspects from organic and biological fertilizer use in agriculture, the current study was to assess the response of okra, in terms of growth and yield to different mulching materials and soil amendments

MATERIALS AND METHODS

Study Site

The site lies between latitude 08°51′ and 09°37′N and longitude of 7°20′ and 7°51′E and was characterized by a maximum temperature of 32 °C and minimum of 22 °C. The soil was of sandy loam textural class. The climate of the area is characterized by two seasons – the rainy season usually from May to October while the remaining part of the year remains dry.

Collection and processing of soil samples

The study was carried out in pots and rainfed and the set up lasted from April and to July, 2014. Soil used was collected from the Teaching and Research Farm of the Faculty of Agriculture, University of Abuja. Soil samples were randomly taken with soil auger at a depth of 0-15 cm to make a composite sample. After thorough mixing, a representative subsample was taken for soil physical and chemical properties. Thereafter, soils were sieved and weighed into perforated 5 kg pot.

Experimental setup and Design

Each pot of processed soil was moistened and allowed to drain prior to planting. Pre-germinated seeds were sown at the rate of two seeds per bag. The okra variety 204-2 used was collected from the Department of Agronomy, University of Ibadan. Plants were thinned to 1 plant per bag at 2 weeks after planting (WAP). The treatments were; three levels of soil amendments (inorganic fertilizer, mycorrhizal inoculants and no-amendment) and four mulch types (leguminous live mulch (100 g per pot), plastic mulch (200 g per pot), wood shaving (100 g per pot), and no-mulch). The leguminous live mulch was made of *Calopogonium mucunoides* Desv. Inorganic fertilizer- (NPK 15:15:15) was applied at 0.45 g/pot by ring method and mycorrhizal inoculant, Glomus mosseae, at 10 g per pot. These treatments were applied two weeks after planting (WAP) and laid out as factorial experiment in a completely randomized design (CRD) with three replicates. Weeding was done regularly by hand pulling during the period of the experiment. The experiment lasted for 14 weeks.

Data Collection and Statistical Analysis

Data were collected on growth and yield parameters such as the number of leaves, height of plant (cm), pods fresh weight (g) and number per pot, shoot and root fresh weight and dry weight (g) and pods dry weight (g). Data were subjected to PROC GLM for the analysis of variance (ANOVA) in the Statistical Analysis System (SAS, 2008), version 9.2. Significantly different means were separated using the Duncan multiple range test at $P \leq 0.05$. PROC MIXED was used to show, with the Least Square Mean option, the significant interactional treatments. A spearman correlation was also used to assess the degree of relationship between root and shoot parameters.

RESULTS

The physico–chemical properties of the soil used for the experiment are given in Table 1. The soil was sandy loam with moderate to low nutrient content. Soil pH water was neutral (7.04), and soil organic matter and total nitrogen content were respectively 5.23 and 0.73 g kg^{-1}.

Mulching and soil amendment effects on okra root development

From the statistical analysis, it was observed that mulching significantly influenced the development of okra's root (Table 2). The longest root lengths were obtained with plastic (53.78 cm) and legume (53.03 cm) mulches while the shortest was observed under wood shaving mulch (30.44 cm). The highest root fresh (79.28 g) and dry (23.56 g) weight were obtained as well, with the utilization of plastic mulch.

The treatments applied as soil amendment also significantly influenced root development. The highest mean values for root length (58.54 cm), root fresh (78.58 g) and dry weight (24.46 g) were obtained when no amendment was applied. As well, the interaction between mulches and soil amendment significantly affected root growth parameters (Table 3).

Mulching and soil amendment effects on growth parameters and pod development

Mulches, soil amendment and their interaction did not influence plant height and number of leaves from 2 to 12 WAP. At 14 WAP however, the height was significantly influenced by the treatments; legumes and plastic mulches had the highest plant height of 91.33 cm and 87.89 cm respectively. However, soil amendment did not affect plant height (Table 4).

Table 1: Chemical and physical characteristics of experimental soil

Properties	Values
pH (H_2O)	7.04
OC (g kg^{-1})	5.23
N (g kg^{-1})	0.73
Mehlich P (mg kg^{-1})	4.65
Ca (cmol(+) kg^{-1})	4.4
Mg (cmol(+) kg^{-1})	0.85
K (cmol(+) kg^{-1})	0.21
Na (cmol(+) kg^{-1})	0.36
Exch. Acidity (cmol(+) kg^{-1})	0.4
ECEC (cmol(+) kg^{-1})	6.22
Zn (mg kg^{-1})	5.3
Cu (mg kg^{-1})	0.3
Mn (mg kg^{-1})	22.7
Fe (mg kg^{-1})	14.5
Sand (g kg^{-1})	718
Silt (g kg^{-1})	214
Clay (g kg^{-1})	68
Textural class	Sandy loam

Table 2: Effect of mulching and soil amendment on root development of okra

Treatment	Root		
	Length (cm)	Fresh weight (g)	Dry weight (g)
Mulches			
Plastic	53.78 a	79.28 a	23.56 a
Legume	53.03 a	74.11 a	20 ab
Wood shaving	30.44 c	29.44 b	13 b
No-mulch	41.44 b	60.88 a	18.29 ab
Soil amendment			
AMF	41.88 b	48.58 b	12.25 b
Fertilizer	32.89 c	57.32 ab	20.80 a
No amendment	58.54 a	76.85 a	24.46 a

Means followed by the same letter within a treatment for each parameter are not statistically different according to Duncan multiple range test at $P \leq 0.05$

Table 3: Mulches and soil amendment interaction effect on okra root development

Treatments	Root		
	Length (cm)	Fresh weight (g)	Dry weight (g)
Mulch (M)	2780.5***	4581.2**	105308.6**
Soil amendment (SA)	3215.5***	2688.2*	76260.4*
M x SA	1124.7*	3187.0**	83778.1**

The values represent the mean square of each parameter ***, **, *: significant at *P*= 0.001, 0.01 and 0.05 respectively.

Table 4: Effects of mulching and soil amendment on okra plant height and leaves number at 14 WAP and pods yields

Treatment	Plant height (cm)	Number. of leaves	Pod dry weight (g)
Mulch			
Plastic	87.89 a	60.67 a	26.44 a
Legume	91.33 a	56.78 a	33.00 a
Wood shaving	65.13 b	21.78 b	24.13 a
No mulch	75.13 ab	45.13 a	35.50 a
Soil amendment			
AMF	72.67 a	33.25 b	20.42 b
Fertilizer	79.55 a	40.46 b	24.28 b
No amendment	89.82 a	64.17 a	43.41 a

Means followed by the same letter within a treatment for each parameter are not statistically different according to Duncan multiple range test at $P \leq 0.05$

Table 5: Mulch and soil amendment interaction effects on okra growth and pod development

Treatments	Plant Height	Shoot fresh weight (g)	Shoot dry weight (g)	Pod dry weight (g)
Mulch	1379.3*	105308.6***	2209.3***	126.8 ns
Soil amendment	730.4ns	76260.4*	4984.8***	1527.7*
mulch*Soil amendment	1731.2**	83778.1**	6305.9***	1333.1**

The values represent the mean square of each parameter; ***, **, *: significant at *P*= 0.001, 0.01 and 0.05 respectively, ns: not significant

Table 6: Effect of mulch type and soil amendment interaction on the shoot dry weight of Okra

Effect	Mulch	Soil amendment	Estimate	Pr > |t|
mulch*Soil amendment	Legumes	Fertilizer	79	<.0001
mulch* Soil amendment	Legumes	Mycorrhiza	89	<.0001
mulch* Soil amendment	Legumes	No-amendment	59.6667	<.0001
mulch* Soil amendment	**No-mulch**	**Fertilizer**	**8**	**0.5311**
mulch* Soil amendment	No-mulch	Mycorrhiza	49.5	<.0001
mulch* Soil amendment	No-mulch	No-amendment	113.33	<.0001
mulch* Soil amendment	Plastic	Fertilizer	101.17	<.0001
mulch* Soil amendment	Plastic	Mycorrhiza	26.6667	0.0161
mulch* Soil amendment	Plastic	No-amendment	119.67	<.0001
mulch* Soil amendment	Wood shaving	Fertilizer	112.67	<.0001
mulch* Soil amendment	**Wood shaving**	**Mycorrhiza**	**5**	**0.631**
mulch* Soil amendment	Wood shaving	No-amendment	28.6667	0.0104

The number of leaves was significantly affected by mulches, soil amendment and their interaction. The highest number of leaves was obtained with plastic mulch, even though no significant difference was observed between plastic and legume mulches on the latter parameter. Furthermore, treatment without soil amendment was more efficient in increasing number of leaves and pod dry weight of okra. The interaction between mulch and soil amendment had a significant ($p \leq 0.01$) effect on plant height, shoot and pod weight (Table 5). Mycorrhizal inoculation effect under legume mulch resulted in an increase of 90 % and 79.8 % for fresh and dry shoot weight respectively. In contrary, mycorrhizal inoculation resulted in decline of 61 % and 46 % under plastic mulch and 86.7 and 89.9 % under wood shaving treatment for fresh and dry shoot weight, respectively.

Table 7: Spearman Correlation coefficient between below and above ground variables of Okra.

	Plant height (cm)	No of leaves	Shoot fresh weight (g)	Shoot dry weight (g)	Pod dry weight (g)
RFW	0.64***	0.80***	0.93***	0.80***	0.43*
RL	0.56***	0.76***	0.69***	0.59***	0.54***
RDW	0.60***	0.52**	0.73***	0.87***	0.58***

Where: RFW, Root Fresh Weight; RL, Root Length; RDW, Root Dry Weight; ***, **, *: significant at *P*= 0.001, 0.01 and 0.05 respectively.

Further analysis conducted with the PROC Mixed on shoot dry weight, an important variable of crop growth, showed that only two interactions did not have significant effects (Table 6). The interaction between no-amendment and fertilizer, and the one between wood shaving and mycorrhizal treatments did not significantly increase okra shoot dry weight. The assessment of the relationship between root and shoot parameters with the Spearman correlation coefficients revealed strong and significant correlation between those parameters. The highest correlation coefficient was observed between root dry weight and shoot dry weight with 0.87.

DISCUSSION

Mulch materials significantly ($p \leq 0.05$) influenced the number of leaves, plant height, shoots and root fresh weight. This result agrees with the findings of Iniobong *et al.* (2010), in which significant increase on all the yield components of cassava resulting from mulching was reported. This could be attributed to the efficiency of mulch in conservation of moisture, improvement of both beneath and above soil surface microclimate, light reflection and great weed control. Organic mulch in addition improves soil nutrients (Parma and Sharma, 1996; Bhardwaj, 2013) Use of plastic mulch favored the plant's growth environment compared to saw dust or no mulch treatment; which could be mostly through enhanced soil temperatures and moisture conservation. Increased crop productivity resulting from the use of plastic mulch is well documented (Davis, 1994; Lugo *et al*., 2008; Laugale *et al*., 2012; Liu *et al* 2012; Overbeck *et al*., 2013). However, its benefits are of short-term and highly limited as soil structure and fertility cannot be enhanced under plastic mulch (Davis, 1994; Grassbaugh *et al*., 2004). Besides, plastic mulch materials could pose an environmental pollution problem in terms disposal (Davis, 1994) and may be of a great a threat to soil health; affecting soils organisms' diversity and functions in terms of organic matter decomposition, nutrient mineralization and carbon sequestration (Stork and Eggleton, 1992; Lugo *et al*., 2008). Live mulch or cover crop is more preferable over synthetic mulches although there could be competition among crops (Wile *et al*., 1989). Surface organic mulch such as leguminous plant materials could be a better option as it is highly biodegradable while improving the soil fertility yet does not interfere/ compete with growing crop (Grassbaugh *et al*., 2004).

Soil amendment significantly ($p \leq 0.05$) affected the number of leaves; shoot fresh and dry weight, root length and pod dry weight. On one hand, there was no significant difference between yield under fertilizer application and no amendment treatment. On the other hand, a significant lower mean values were observed under AMF treatment. This non-performance of used AMF species could have resulted from its weak competency vis a vis of the indigenous AMF species. The interactive effect of mulch*soil amendments significantly ($p \leq 0.05$) affected all parameters. Pod dry weight as well as root fresh weight showed best performance under legume mulch x mycorrhiza treatment. This higher biomass yield from AMF treated and legume mulched plants indicates a positive synergistic effect of these two factors. Boswell *et al.* (1998) attributed high nutrient uptake in inoculated and mulched plants to be due to additional nutrients made available to the soil and increased P uptake by the crop, resulting to increased root growth and development, which in turn could increase the uptake of other nutrients and water.

CONCLUSION

In conclusion, legume mulch (*Calopogonium mucunoides*) is of organic source and also readily available among poor resource farmers. Plastic mulch although showed significantly higher performance over wood shaving, its output did not differ significantly with that obtained from legume mulch. The use of plastic materials in the soil could with time pose adverse environmental problem as a large portion of these plastics are left on the field.

Finally, the positive mycorrhizae x legume mulch interaction is environmental friendly and could be further manipulated for a sustainable increase in okra productivity.

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