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GROWTH AND YIELD RESPONSES OF CARROT (*Daucus carota* L.) TO DIFFERENT LEVELS OF OIL PALM REFUSE BUNCH ASH IN AN ULTISOLS ENVIRONMENT

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ABSTRACT

A field experiment was conducted from July – October, 2015 and 2016 at the Experimental Farm of the Faculty of Agriculture, University of Benin, Benin City, Nigeria, to determine the effect of oil palm bunch ash on the growth and yield of carrot (*Daucus carota* L.) and the soil post-harvest chemical properties. The study involved the application of oil palm refuse bunch ash at six (6) levels (0, 2, 4, 6, 8 and 10 t ha^{-1}). The treatments were arranged in a randomized complete block design (RCBD) with four replications. Data were collected on growth variables (number of leaves and height of plant) at two (2) weeks interval. After harvest, data were collected on root length, root girth, leaf weight, root weight, and root yield. The results of the trial showed that non-oil palm refuse bunch ash (non-OPRBA) plants had shorter plants and fewer number of leaves than OPRBA treated plants. At harvest, weight of aerial portion, root:shoot and root yield were highest with plants treated with PORBA at 10 t ha^{-1}. Postharvest soil chemical properties indicated PORB ash enriched the soil with organic carbon, total N, available P and exchangeable cations (Ca, K, Mg and Na). PORBA application rate of 10 t ha^{-1} is hereby recommended for carrot growers in the humid ultisols environment.

Keywords: Number of leaves, plant height, potassium, soil chemical properties, root yield

INTRODUCTION

Carrot (*Daucus carota* L.) contains appreciable amount of carotene (10mg/100mg), thiamine (0.04mg/100mg) and riboflavin (0.05mg/100mg) (Sharfuddin and Siddique, 1985). It is also an excellent source of iron, vitamin B, vitamin C and sugar (Yawalker, 1985). Besides, it has some important medicinal values and its plays important role in to protecting blindness in children by providing vitamin A. it is consumed fresh or cooked, either alone or with other vegetables, in the preparation of stew, curries and pie. Its fresh grated roots are eaten with salads. It also helps to increase resistance against blood and eye diseases (Hassan *et al*., 2005).

The average yield of carrot in Nigeria is low with 15t ha^{-1} compared to United States of America 170t ha^{-1} (FAOSTAT, 2012). The low yield per hectare in Nigeria is due to poor cultural practices such as non-use of agro-industrial residues (organic fertilizer) among other factors. This implied the improvement of soil fertility can enhance the productivity of carrot. One option of improving soil fertility among resource-poor farmers is the judicious use oil palm refuse bunch ash as soil organic amendments (Adjei-Nsiah, 2012). This is because, apart from nutrients release to the crops, agro-industrial and agricultural residues also have positive residual effects on the soil chemical and physical properties. Ahaiwe (2008) reported from his study on performance of oil palm refuse bunch ash on ginger that the treatment enhanced growth and yield. However, necessary information regarding the use of different levels of oil palm refuse bunch ash on carrot production under ultisols condition is scanty. Hence, this study was conducted to evaluate the influence of palm bunch ash on the growth and yield of carrot in an ultisols environment.

MATERIALS AND METHODS

Field study was conducted during July – October of 2015 and 2016 at the experimental Farm of the Faculty of Agriculture, University of Benin, Benin City (Latitude 6^0 19N and Longitude 5^0 39' E). The area fall under the rain forest zone of Edo State, Nigeria. The dominant vegetation in the site before cultivation was guinea grass (*Panicum maximum* Jasq).

The treatment comprised six levels (0, 2, 4, 6, 8, 10 t ha^{-1}) of oil palm refuse bunch ash and laid out in a randomized complete block design (RCBD) with four replications. Each plot measured 1 x 2 m spaced 0.50 m and 1.00 m apart. The experimental site therefore occupied area of 123.5 m^2.

The land was manually cleared, marked out into blocks and plots and beds were constructed manually using hoe and spade. Cured poultry manure was applied on marked out plots as basal at 15t ha^{-1} four weeks before sowing. Carrots at the rate of 3 kg ha^{-1} were sown on 25 July. The seeds were sown in-situ at a spacing of 20 x 15cm at three seeds per stand at a depth of 1.5cm. The seedlings were thinned to one per stand twelve days after sowing. Oil palm refuse bunch ash was incorporated at two weeks after sowing (WAS) according to treatments. The plots were weed-free and rain-fed. Rouging of diseased plants and handpicking of pests were done when required. Carrots were harvested at 90 days (23 October) from sowing when the leaves become pale yellow.

Data were collected on 10 randomly selected plants from the inner rows of each plot on plant height, number of leaves on biweekly bases starting from four WAS. At harvest, carrot root weights, aerial leaf weight, shoot: root and root yield were taken. After harvest, postharvest soil chemical property analysis was carried out using laboratory procedures as described by Mylavarapus and Kennelley (2002). The data collected were combined for two years and analyzed using analysis of variance. Significant differences among treatment means were separated using the least significant Difference (LSD) at 5 % level of significant.

RESULTS

Properties of the Soil and Oil Palm Refuse Bunch Ash

The dominant soil type at the experimental site was sandy loam and the soil order was ultisols. The soil on laboratory analysis had pH, organic C, total N, available P, exchangeable Ca, Mg, K, Na and exchangeable acidity of 5.60, 18.10 g kg^{-1}, 0.09 g kg^{-1}, 6.45 mg kg^{-1}, 0.36 cmol kg^{-1}, 1.31 cmol kg^{-1}, 0.40 cmol kg^{-1}, 0.12 cmol kg^{-1} and 0.12 cmol kg^{-1}, respectively (Table 1).

Table 1: Some properties of the experimental soil before cropping and chemical composition of oil palm refuse bunch ash (OPRBA)

Soil Property	Soil	OPRBA
pH (H_2O) 1:1	5.60	10.80
Organic carbon (g kg^{-1})	18.10	31.10
Organic matter (g kg^{-1})	31.13	53.49
Total nitrogen (g kg^{-1})	0.09	2.10
Available phosphorus (mg kg^{-1})	6.45	18.22
Exchangeable cations (cmol kg^{-1})		
Calcium	0.36	20.60
Magnesium	1.31	86.50
Potassium	0.40	15.70
Exchangeable acidity (cmol kg^{-1})	0.12	NA

NA - Not applicable

The chemical composition of OPRBA from the laboratory analysis recorded 10.80, 31.10 g kg^{-1}, 2.10 g kg^{-1}, 18.22 mg kg^{-1}, 20.60 cmol kg^{-1}, 86.50 cmol kg^{-1}, 15.70 cmol kg^{-1} and 3.24 cmol kg^{-1} for pH, organic C, total N, available P, exchangeable K, Ca, Mg and Na, respectively as presented in Table 1.

Growth of Carrot

Table 2 shows the effects of oil palm refuse bunch ash on plant height and number of leaves. The treatments significantly influenced the plant height and number of leaves throughout the periods of sampling. At four WAS, plant height varied between 7.38 and 12.62cm for control and plants treated with 4t ha^{-1}, respectively. The tallest plants were observed in plots treated with OPRBA at 4t ha^{-1}but they were statistically comparable to plants found on 2, 6 and 10t ha^{-1} treated plots. This distribution trend was repeated at six and eight WAS. Throughout the assessment periods, the least number of leaves per plants were observed in non-OPRBA plots and significantly lower than PORBA treated plants except at 6 WAT where plants treated with 8t ha^{-1} OPRBA and control plants had statistically similar number of leaves.

Root Yield and its Components of Carrot

Root yield and its components were influenced by OPRBA as presented in Table 3. OPRBA treated plants were significantly different from non-OPRBA plants in all yield components except harvest index. The weight of aerial portion per plant after harvest varied between 5.00 and 16.235 g for non-OPRBA plant and OPRBA treated plants at the application rate of 10 t ha^{-1}, respectively. All plants treated with OPRBA had significantly higher aerial portion higher than non-OPRBA plants. All OPRBA treated plants had significantly heavier roots than non-OPRBA plants. The heaviest roots (51.00 g) were harvested from plots treated with OPRBA application rate of 10 t ha^{-1} and the least were observed on non-OPRBA plants. Only plants treated with OPRBA applied at 10 t ha^{-1} had higher root: shoot ratio than non-OPRBA plants.

Root yield varied between 2.67 and 17.00 t ha^{-1} for non-OPRBA plants and plants treated with OPRBA applied at 10 t ha^{-1}, respectively. Plants treated with OPRBA rates at 4 – 6 t ha^{-1} had similar root yields as non-OPRBA plants. OPRBA applied at 10 t ha^{-1} had the highest root yield (17.00 t ha^{-1}) followed by plants treated with OPRBA applied at 2 and 8 t ha^{-1}.

Table 2: Effects of OPRBA on plant height and number of leaves of carrot plants

OPRBA	Plant height (cm) weeks after sowing			Number of leaves weeks after sowing		
(t ha^{-1})	4	6	8	4	6	8
0	7.38	14.50	26.00	42.00	80.00	97.20
2	10.62	20.00	30.75	55.00	114.00	129.80
4	12.62	23.75	35.00	62.20	115.20	132.00
6	11.25	20.88	33.38	60.80	104.00	120.50
8	9.75	19.75	32.38	56.20	90.00	101.20
10	10.45	21.12	32.00	63.20	109.50	120.80
Mean	10.35	20.00	31.58	56.60	102.10	116.90
SE	0.737	2.494	1.289	4.120	6.380	6.970
LSD (0.05)	2.223	5.316	3.884	12.420	19.230	21.000

Table 3: Effects of OPRBA on root yield and its component of carrot

OPRBA (t ha^{-1})	Weight of aerial portion (g $plant^{-1}$)	Root weight (g $plant^{-1}$)	Root: Shoot	Root yield (t ha^{-1})	Harvest index
0	5.00	8.00	1.33	2.67	0.61
2	7.75	18.20	2.62	4.42	0.65
4	8.25	14.00	1.34	4.00	0.64
6	9.50	12.50	1.68	4.17	0.57
8	11.50	16.50	1.80	5.50	0.59
10	16.25	51.00	3.17	17.00	0.76
Mean	9.71	20.00	2.00	6.29	0.63
SE	1.196	2.880	0.510	0.563	0.053
LSD (0.05)	3.604	2.679	1.539	1.697	ns

ns – Not significant at 0.05 level of probability

Postharvest Soil Chemical Properties

The postharvest soil chemical properties as influenced by OPRBA are presented in Table 4. OPRBA had significant effect on all the soil chemical properties assessed. pH increased with increase in the application rate of OPRBA unto the highest level. This distribution pattern was also observed for organic carbon, total N and available P. OPRBA application rates of 6-10 t ha^{-1} had exchangeable Ca^{2+} greater than that of non-OPRBA treated plots. This distribution trend was also observed on exchangeable Mg^{2+}, K^+ and Na^+ but for exchangeable acidity (H^+ and Al^{3+}), there were significant decrease in exchangeable H^+ and Al^{3+} with increase in OPRBA application rate unto the highest level. However, OPRBA application rates of 2 and 4 to ha^{-1} had exchangeable H^+ and Al^{3+} statistically compared to that of the non-OPRBA treated plants.

Table 4: Effect of OPRBA on postharvest soil chemical properties

Treatment (t ha^{-1})	pH	Org. C (g kg^{-1})	Total N (g kg^{-1})	Avail. P (mgkg^{-1})	Exchangeable cation (cmol k^{-1}) Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+	Al^{3+}
0	5.33	7.13	0.73	8.62	0.78	0.25	0.25	0.16	1.12	0.63
2	5.42	10.80	0.98	9.45	0.82	0.31	0.27	0.18	1.10	0.60
4	5.64	15.70	1.05	11.20	0.82	0.30	0.26	0.18	1.12	0.55
6	5.81	18.90	1.14	14.50	0.92	0.32	0.31	0.20	1.00	0.42
8	5.80	20.20	1.18	16.60	1.06	0.35	0.31	0.22	0.78	0.40
10	6.230	22.60	1.24	16.80	1.25	0.52	0.30	0.22	0.66	0.24
Mean	5.71	15.89	1.05	12.86	0.94	0.34	0.28	0.19	0.96	0.47
LSD (0.05)	0.189	0.690	0.114	0.412	0.051	0.076	0.021	0.020	0.145	0.111

Correlation Matrix among Postharvest Soil Chemical Properties

The correlation matrix among postharvest soil chemical properties is presented in Table 5. Exchangeable Al^{3+} was negatively correlated with pH (-0.79), total N (-0.74), organic carbon (-0.84), exchangeable Na^+ (-0.72), exchangeable Mg (-0.74), exchangeable K^+ (-0.46), exchangeable Ca (-0.86) and available P (-0.85) but positively correlated with exchangeable H^+ (0.78). Available P correlation with exchangeable H^+ was negative (-0.82). Available P correlation with pH, total N, organic carbon, exchangeable Na^+, exchangeable Mg, exchangeable K^+ and exchangeable Ca^{2+} were positive with coefficients of 0.82, 0.84, 0.96, 0.77, 0.60, 0.44, and 0.87, respectively.

Table 5: correlation matrix among postharvest soil chemical properties

Al	1.00									
Av. P	-0.85*	1.00								
Ca	-0.86*	0.87*	1.00							
H	0.78*	-0.82*	-0.89*	1.00						
K	-0.46*	0.44*	0.41*	-0.33*	1.00					
Mg	-0.74*	0.60*	0.85*	-0.69*	0.40*	1.00				
Na	-0.72*	0.77*	0.75*	-0.59*	0.67*	0.50*	1.00			
Org C	-0.84*	0.96*	0.82*	-0.74*	0.44*	0.56*	0.74*	1.00		
Total N	-0.74*	0.84*	0.74*	-0.61*	0.35*	0.45*	0.69*	0.90*	1.00	
pH	-0.79*	0.82*	0.84*	-0.71*	0.36*	0.59*	0.73*	0.83*	0.80*	1.00
	Al	Av. P	Ca	H	K	Mg	Na	Org C	Total N	pH

* Significant at 0.05 level of probability

Exchangeable Ca^{2+} was negatively correlated with exchangeable H^+ (0.78) but positively correlated with pH (0.84), total N (0.84), organic carbon (0.82), exchangeable Na^+(0.89). Exchangeable H^+ correlation with pH, total N, organic carbon, exchangeable Na, exchangeable magnesium and exchangeable K^+ with coefficients of -0.71, -0.61, -0.74, -

0.59, -0.69 and -0.33, respectively. Exchangeable K^+ correlated positively with pH, total N, organic carbon, exchangeable Na^+ and exchangeable $Mg^{2+}$with coefficient of 0.36, 0.35, 0.44, 0.67 and 0.40, respectively. Exchangeable Mg^{2+} correlated positively with pH (0.59), total N, (0.45), organic carbon (0.56) and exchangeable Na^+ (0.50). Exchangeable Na^+ correlation with pH, total N and organic carbon were positive with a coefficient of 0.73, 0.69 and 0.74, respectively. Organic carbon positively correlated with pH (0.83) and total N (0.90). Total N correlation with pH was positive (r=0.80).

DISCUSSION

The soil of the experimental site was acidic sand with low nutrient content. This finding is in agreement with Awodun *et al*. (2007) who reported that most soils in the humid tropical regions are acidic and low in plant nutrients due to the high rainfall regime and intensity which is associated with leaching of nutrients. Any meaningful production of crop from this soil will be impossible without supplemented fertilizer.

Oil palm refuse bunch ash (OPRBA) on analysis contained nutrients (N, P, K, Ca, Mg and Na) in appreciable amount and alkaline in nature. This finding is in agreement with the observation of Lim and Zahara (2008) who reported that OPRBA contained plant nutrients in abundant that can be utilized as fertilizer supplement, organic mulching material or composted into readily available organic fertilizer for crop production. Adjei-Nsiah (2012) also reported that OPRBA supplies organic carbon, nitrogen, phosphorus, calcium and magnesium. This findings justified oil palm refuse bunch ash as soil amendments for improving the soil fertility without resorting to the use of inorganic fertilizer.

The enhancement of plant growth as evidenced through higher plant height and number of leaves associated with OPRBA treated plants over control plants could have resulted from the improvement in the pH. This led to abundant supplied of nutrients to the plants for growth and development. It could also be as a result of high potassium content of the ash which increases the efficiency of the plant for utilization of nitrogen that enhances the plant growth (Shah *et al*., 2013). Potassium is necessary for many functions, including carbohydrate metabolism, enzyme activation, osmo-regulation and efficient use of water, nitrogen uptake and protein synthesis and translocation of assimilates (Clarkson and Hanson, 1980). This finding is in agreement with Ezekiel *et al*., (2003) who reported that oil palm refuse bunch ash was found to increase nutrient supply to cassava significantly. Non-OPRBA plants had shorter plants and fewer numbers of leaves as they had to rely on the native soil fertility which, from the results of chemical analysis was deficient in plant nutrients.

The tallness of the OPRBA treated plants enhanced more efficient interception of solar radiation and contributed to an increase in root yield of carrot over non-OPRBA treated plants. The tallness of OPRBA plants is a precursor to greater amount of assimilates and this allows more translocation to the roots. Increased number of leaves leads to greater production of assimilates due to better utilization of solar radiation. Higher number of leaves favoured photosynthesis and therefore the more leaves possessed by plants led to improved yield (Law-Ogbomo and Remison, 2008).

The incease in root yield and its components due to OPRBA application was attributed to adequate nutrient availability in the soil which promoted plant nutrient uptake and subsequently, yield increase. This finding conforms the report of Ojeniyi *et al* (2009) reported that high root yield in the use of OPRBA on cassava. The low root yield of carrot associated with non-OPRBA could probably be due to low potassium content of the soil. Potassium helps in vigorous plant growth and its deficiency can lead to stunted growth and reduction in yield and marketable fruits (Vans and George, 1985).

Postharvest soil chemical analysis indicated that non-OPRBA plots had lower pH compared to OPRBA treated plant. This finding emphasized that OPRBA reduced acidity (Awodun *et al*., 2007). The liming ability of OPRBA could be due to high content of exchangeable cations which displaced exchangeable H^+ as evidenced through negative correlation between exchangeable cations and exchangeable H^+. This is also evidenced through decreased in exchangeable H^+ as OPRBA increased and positive correlation between pH and organic carbon. This association indicated that an increase in OPRBA application rate in response to organic carbon had substantially contributed to reduced acidity. Awodun *et al*. (2007) also found that OPRBA improved soil chemical properties by supplying organic matter.

OPRBA increased organic carbon, total N, available P, exchangeable cations (Ca, K, Mg, and Na) of status of the soil. This agrees with Safo *et al* (1997) who reported that OPRBA increased soil pH, available P and effective cation exchange capacity of Ghanaian soil.

pH positive correlation with total N, organic carbon available P and exchangeablecations (Na, Mg K and Ca) is an indication that increased in pH will bring about more availability of total N, available P and exchangeable cations in the soil for upward supply to the plant for uptake and utilizations.

CONCLUSION

This study showed that, the soil was acidic sand with low plant nutrients content. Oil palm refuse bunch ash enhanced the growth and yield of carrot. Root yield was maximized at 10t ha^{-1}. Post-harvest soil chemical properties indicated that PORBA enriched the soil with organic carbon, total N, available P and exchangeable cations (Ca, K, Mg and Na).Carrot growers should apply OPRBA as soil amendment to supplement the soil with plant nutrients at rate of 10t ha^{-1}. However, further research at levels higher than 10 t ha^{-1} in order ascertained the actual level of yield maximization.

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