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Influence of Wood Ash Concentration on Coastal Plain Soil, Growth and Yield of Tomato (*Solanum lycopersicum*) in a Humid Tropical Zone of South Eastern Nigeria

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Abstract

A pot experiment was conducted at the Screen house of the Department of Soil Science, Akwa Ibom State University in 2023 to determine the wood ash effects on the production of tomato. The experiment was laid out in a Randomized Complete Block Design (RCDB) and replicated three times. Ten (10) kg of sieved soil samples were placed in 12 litre buckets with drainage holes at the bottom. Wood ash at the rates of 0.00, 0.03, 0.06, 0.09, 1.20 and 1.50 gha^{-1} were mixed with the soil and irrigated to field capacity before transplanting. Data on soil, growth and the yield parameters of tomato were collected and subjected to statistical analysis. Results indicated that wood ash had the following chemical properties; pH 10.7, Av.P 33.8mgkg, K-24.2gkg^{-1}, Ca-48.0gkg^{-1}, Mg-26.4gkg^{-1}, Total N-4.56gkg^{-1} and Organic C -12.07%. Results also indicated that the soil nutrient contents increased with increasing rate of wood ash applications. The pH values significantly increased linearly. It was raised from 4.78 (control) to 7.89 at wood ash

application rate of 1.5ghaˉ¹ with R^2 = 0.978 while exchangeable acidity decreased with increased rate of wood ash applications R^2 = 0.976. The result revealed that the growth and yield of tomatoes decreases as wood ash application increases. Wood ash at the rate of (0.030ghaˉ¹) produced the best yield. The trend were: 0.03ghaˉ¹ (9.95thaˉ¹), > control (7.97thaˉ¹) >0.06ghaˉ¹(6.14thaˉ¹) 0.09ghaˉ¹ (3.97thaˉ¹) > 1.20ghaˉ¹ (2.45thaˉ¹) > 1.50 ghaˉ¹ (2.20thaˉ¹). Based on the results 0.03ghaˉ¹ of wood ash is recommended for tomato production with this soil.

Keyword: Wood ash, Coastal plain soil, Soil properties, Tomatoes

1.0 Introduction

Soils in South Eastern Nigeria are generally acidic due to the nature of the parent material and heavy rainfall which leads to heavy weathering and leaching (Owolabi *et al.*, 2003). It has been reported by several researchers (Umoh *et al.*, 2018; Umoh *et al.*, 2019; Sunday *et al.*, 2020) that sandy soil are highly prone to leaching of cationic nutrients (K and P), leading to soil nutrient losses and the limited nutrient elements remaining are fixed in the soil which consequently cause deficiency and low yield of crops, (Umoh *et al*., 2014; Umoh *et al*., 2019; Umoh *et al*., 2017) reported high fixation of P and K in acidic soils.

The maintenance of soil fertility is essential in achieving and sustaining high crop yields (Gagnon, 2012).The use of organic wastes and other soil amendment materials such as lime is highly recommended (Owolabi *et al.*, 2003; Ekwere, 2024). Increased acidity and soil nutrient imbalance have drawn the attention of researchers to the use of agricultural waste that could serve as a liming material and fertilizer (Obi and Ekperigin, 2001).These wastes are available, acceptable and affordable by the resource poor farmers. Odedina *et al.*, (2003), reported that wood, cocoa husk, sawdust and rice bran ash contains high amount of N,P,K, Ca and Mg as macro nutrient element, which is needed by plants in large quantities (Nafziger, 2002). They also reported that the application of wood ash increased the fruit weight and yield of tomato and pepper. Obi and Ekperigin, (2001) studied the effects of liming materials such as wood ash and dust to which legumes were incorporated. Results showed that the combined effects of poultry manure and lime increased maize yield. Udoh *et al.*, (2021) also found that the yield of cocoyam increased with the applications of eggshell ash on coastal plain sand soils. Ojeniyi *et al.*, (2002) found that yield and nutrient contents of vegetables were greatly improved due to the application of wood ash. Owolabi e*t al.*,(2003) reported that ash derived from burnt

vegetation is known to reduce soil acidity, increase the availability of cationic nutrients and improve the yield of maize.

Tomato belongs to the *Solaneceae* group of the night shade family and produce fruit which is a true berry. It has an enlarged and succulent placenta bearing small seeds (Audu *et al.,* 2019). Tomato is one of the popular vegetables consumed by most people. It is rich in nutrients. The amount and types of fertilizer supplied to vegetables during growth can influence, not only its yield but also its nutrient composition and taste (Akpan *et al*., 2022; Efretuei *et al.,* 2023; Ekwere *et al*., 2024). Nutrients such as N, P, K, Ca, Mg and S, are needed in large amounts by tomato for normal growth and reproduction. Others such as Fe, Cu, Mo and Zn are needed in a small quantity (Audu *et al.,* 2019). Application with Ca and Mg through liming will raise soil pH to 7.0 and is considered moderate for tomato (Obi and Ekperigin, 2001). Tomatoes grown in the screen house should be supplied with adequate fertilizer. Applying excess levels of lime can reduce tomato yield and increased fertilizer use efficiency (Obi and Ekperigin, 2001). Information on the use of wood ash to improve the yield of tomato is limited; therefore this research was carried out to ascertain the effects of different levels of wood ash on soil properties and the growth and yield of tomato grown on coastal plain sand in Akwa Ibom State.

2.0 Materials and Methods

2.1 Description of the Study Area

The study was carried out in the Screen house of the Faculty of Agriculture Akwa Ibom state University, Obio Akpa Campus. Obio Akpa is located between latitude 5°17′N and 7°27′N, Longitude 7°27′E and 7°58′E, in the tropical rainforest of South Eastern Nigeria. The area is characterized by heavy rainfall ranging from 2500- 3000°mm along the coastal areas, temperature ranges between 26 - 28°C and relative humidity of 75 - 80% within a year (Umoh *et al*., 2021). The vegetation is rainforest, characterized with trees, shrubs and grasses.

2.2 Soil Sampling and Preparation

The soil for the pot experiment was collected from the Akwa Ibom State University Research Farm at 0- 15cm depth. Samples of the soil were collected air dried, sieved with a 2mm wire mesh and analyzed to determine the chemical and physical properties of the soil after treatment application.

2.3 Wood ash Sampling

The wood ash used for the experiment was collected in March 2023 from the Abak Timber Market, where sawdust (mahogany wood) is disposed of through burning, the wood ash collected washed-dried for hours and then stored in plastic containers. The wood ash was sieved with a2mm mesh and analyzed to establish its nutrient composition.

2.4 Laboratory Study

The following soil parameters were determined as described by Udo *et al.*, (2009). Particle size distribution was determined by the Bouyoucos Hydrometer method using sodium hexametaphosphate as a dispersing agent. The soil pH was measured in water at the soil to water ratio of 1:2.5 using a glass electrode pH meter. Electrical Conductivity was measured in the extract from 1:2.5 soils: water suspension using a conductivity bridge. Soil organic carbon was determined by wet oxidation method and the values were multiplied with the factor of 1.72 (Udo *et al.*, 2009) obtain organic matter. Total nitrogen was determined by the micro Kjeldahl method. Available P in the soil was determined by the Murphy and Rilay method after extraction by Bray P-1extractant. The exchangeable cation in the soil was extracted using NH_4OAC; K and Na in the extracts was measured using flame photometry; while Mg and Ca were determined by atomic absorption spectrophotometry. Effective cation exchangeable capacity (ECEC) was obtained by the summation of the exchangeable cation and the exchangeable acidity. Base saturation (%) was calculated by the sum of exchange cation x 100/ECEC.

2.5 Pot Experiments

The pot experiment was sited at the Screen house of the Faculty of Agriculture, Akwa Ibom State University. The treatments were arranged in a completely randomized design (CRD) with three replications, tomato (*Solanum lycopersicum*) was used as the test crop in the experiment. Ten (10kg) of the soil was weighed into each 12litre plastic pot and moistened to field capacity. There were18 pots representing the 6 treatments and three replicate. The soil was treated with different levels of wood ash according to the recommended rates of 0.05g/ha for coastal plain sand soils: 0.00, 0.03, 0.06, 0.09, 1.20 and 1.50 gha^{-1} were applied. One (1) tomato seedling was planted per pot. NPK fertilizer 15:15:15 at the rate of 0.22g/pot was applied (2WAP) and adequate watering was done at 4 days intervals as recommended by Ekwere and Efretuei (2024).

The treatment combinations were as follows:

1. Soil alone, no NPK and wood ash
2. Soil + 0.22g NPK 15: 15: 15 + 0.03g/ha wood ash
3. Soil + 0.22g NPK 15: 15: 15 + 0.06g/ha wood ash
4. Soil + 0.22g NPK 15: 15: 15 + 0.09g/ha wood ash
5. Soil + 0.22g NPK 15: 15: 15 + 1.20g/ha wood ash
6. Soil + 0.22g NPK 15: 15: 15 + 1.50g/ha wood ash

2.6 Data Collection

Agronomic parameters measured included plant height, number of leaves per plant, stem girth, number of vines, number of fruit and fruit weight/yield. Plant height was measured with a meter rule from the base of the crop (ground level) to the tip of the plants. Number of leaves was assessed by counting the fully opened leaves per plant, stem girth was measured with a venier caliper, and fruit numbers were assessed by counting and fruit weight were determined using electronic weighing balance and (Umoh *et al.*, 2015).

2.7 Data Analysis

The data collected were subjected to analysis of variance (ANOVA) using the Statistical Analysis System Program (SAS, 1989). Means were compared using Fisher's Least Significant Difference (FLSD) at a 5% level of probability.

3.0 Results and Discussion

3.1 Chemical Composition of Wood Ash

The chemical composition of wood ash is shown in Table 3.1. The result revealed the pH value to be 10.7 which is alkaline in nature. The result also indicated that wood ash contained high essential nutrient elements; Potassium had the highest values (48.0g/kg^{-1}) while total nitrogen was the lowest (4.56g/kg^{-1}). This elemental composition is in line with Ojeniyi (2012) who demonstrated that wood ash contained N,P, K,Mg and Ca.

3.2 Physicochemical Properties of Soils used for the Study

The effect of wood ash treatment on physicochemical properties of the soil is shown in Table 3.2. The result revealed that, there was a slight change in particle size distribution of the soil in terms of sand and silt but no significant difference were observed in the clay fraction, though the texture of the soils remain the same. This observation agrees with

Adaikwa *et al.,* (2012) who reported that good soil management practices may slightly raise sand, silt and clay fractions of the soil and improve soil productivity but cannot change textural class. The results of the chemical properties of the soil showed that the addition of wood ash increased soil pH, organic matter (OM), Total nitrogen (TN), phosphorous (P), potassium (K), calcium (Ca),Magnesium (Mg), Sodium (Na), Effective cation exchange capacity (ECEC) as well as Base saturation(Table3.2).The values increased with increasing rates of wood ash application compared to the control treatment (0),but the exchangeable acidity (EA) decreased with increasing rates of wood ash applied and the control being the highest (1.61cmol/kg^{-1}). The observation in terms of nutrient increase could be due to the addition of wood ash which contain nutrient element in high quantity and the decrease in EA could be due to the liming effect. This finding is in agreement with the report of Ojeniyi *et al.,* (2017) which stated that addition of ash to soil, improved soil nutrient level.

3.3 Effect of Wood Ash on the Growth of Tomato

Result of the effect of different rates of wood ash applications on the growth of tomato are shown on table 3.3. Result showed that increasing rates of wood ash applications significantly reduced the growth parameters of tomato but there was no significant difference between application rates in terms of number of leaves and vines (Table 3.3). The result also revealed that applications of 0.03gha^{-1} of wood ash enhanced (significantly and numerically) the following growth parameters; plant height (58.57cm), number of leaves (83.00), stem girth (2.92cm), number of vines (13.00) and number of branches (4.00). The reduced effect of growth parameter at other wood ash application rates could be attributed to increase in the rates of wood ash applied. Agbede (2009) reported that vegetables require pH of 6 to 6.50 to attain optimal yield.

Table 3.1: Chemical composition of wood ash

Parameter		Values
pH (H_20)	-	10.7
Av.P		33.8 ($mgkg^{-1}$)
K	-	24.2 (gkg^{-1})
Ca	-	48.0 (gkg^{-1})
Mg	-	26.4 (gkg^{-1})
TN	-	4.56 (gkg^{-1})
Oc	-	12.07(%)

Table 3.2: Some physicochemical properties of soils

	Sand	Silt	Clay	pH	OM	TN	Av.P	K	Ca	Mg	Na	EA	ECEC	BS
	%				%	%	mgkg^{-1}	cmolkg^{-1}					%	
Treat0	87.40^{b}	5.5^{a}	7.09^{a}	4.87^{f}	3.70^{e}	0.092^{e}	6.79^{d}	1.65^{f}	1.77^{e}	0.93^{f}	0.07^{c}	1.61^{a}	6.03^{f}	73.34^{f}
Treat1	87.03^{c}	5.23^{a}	7.75^{a}	5.48^{e}	3.72^{d}	0.093^{d}	6.11^{e}	1.93^{e}	2.41^{d}	2.10^{e}	0.09^{b}	1.58^{b}	8.10^{e}	80.54^{e}
Treat2	87.68^{a}	5.10^{ab}	7.21^{a}	5.88^{d}	3.72^{d}	0.093^{d}	6.84^{d}	2.24^{d}	2.64^{bc}	2.24^{d}	0.09^{b}	1.52^{c}	8.73^{d}	82.60^{d}
Treat3	87.49^{ab}	5.15^{ab}	7.36^{a}	6.67^{c}	3.76^{c}	0.094^{c}	8.22^{c}	2.63^{c}	2.58^{c}	2.85^{c}	0.09^{b}	1.48^{d}	9.63^{c}	84.65^{c}
Treat4	87.58^{ab}	4.52^{b}	7.90^{a}	6.87^{b}	3.91^{b}	0.098^{b}	8.57^{b}	2.84^{b}	2.68^{b}	2.87^{b}	0.10^{a}	1.46^{e}	9.96^{b}	85.35^{b}
Treat5	87.68^{a}	5.04^{ab}	7.28 ^{a}	7.89^{a}	3.94^{a}	0.099^{a}	8.93^{a}	2.90^{a}	2.81^{a}	3.01^{a}	0.10^{a}	1.43^{f}	10.25^{a}	86.07^{a}

Table 3.3: Effect of wood ash application on the growth parameters of tomato

	Plant height(cm)	No of leaves	Stem girth(cm)	No of vines	No of Branches
Treat0	45.70^{ab}	75.00^{a}	2.43^{ab}	10.00^{a}	2.00^{b}
Treat1	58.57^{a}	83.00^{a}	2.92^{ab}	13.00^{a}	4.00^{a}
Treat2	49.97^{ab}	65.00^{a}	2.13^{ab}	11.00^{a}	3.00^{a}
Treat3	33.60^{b}	72.00^{a}	2.70^{ab}	11.00^{a}	2.00^{b}
Treat4	28.10^{b}	49.00^{a}	2.13^{ab}	7.00^{a}	2.00^{b}
Treat5	30.20^{b}	42.00^{a}	1.58^{b}	9.00^{a}	2.00^{b}

NB: Means with the same superscript on the same column are not significantly different. Treat 0:Soil alone, no NPK and wood ash; Treat1:Soil + 0.22g NPK 15: 15: 15 + 0.03g/ha wood ash; Treat2: Soil + 0.22g NPK 15: 15: 15 + 0.06 g/ha wood ash; Treat3: Soil + 0.22g NPK 15: 15: 15 + 0.09g/ha wood ash; Treat 4: Soil + 0.22g NPK 15: 15: 15 + 1.20g/ha wood ash; Treat5: Soil + 0.22g NPK 15: 15: 15 + 1.50g /hawood ash.

Table 3.4: Effect of wood ash on the yield of tomato

	Wood ash (g/ha)	Number of fruits per pots	Fruit weight (g/pot)	Fruit yield (tons/ha)
Treat0	0	19^{b}	39.33^{b}	7.97^{ab}
Treat1	0.03	25^{a}	49.73^{a}	9.95^{a}
Treat2	0.06	18^{b}	30.70^{b}	6.14^{b}
Treat3	0.09	11^{c}	18.33^{c}	3.67^{c}
Treat4	1.20	9^{cd}	12.27^{c}	2.45^{c}
Treat5	1.50	5^{d}	11.00^{c}	2.20^{c}

NB: Means with the same superscript on the same column are not significantly different. Treat 0:Soil alone, no NPK and wood ash ; Treat1:Soil + 0.22g NPK 15: 15: 15 + 0.03g wood ash; Treat2: Soil + 0.22g NPK 15: 15: 15 + 0.06g wood ash; Treat3: Soil + 0.22g NPK 15: 15: 15 + 0.09g wood ash; Treat 4: Soil + 0.22g NPK 15: 15: 15 + 1.20g wood ash; Treat5: Soil + 0.22g NPK 15: 15: 15 + 1.50g wood ash.

3.4 Effect of Wood Ash Rates on the Yield of Tomatoes

Results of the effect of wood ash rates on the yield of tomatoes are shown in Table 3.4. Result revealed that application of 0.03g ha^{-1} of wood ash enhanced the following yield parameter compared to other rates, number of fruits, fruit weight. The yield were in these order; $0.03gha^{-1}(9.95t\ ha^{-1})>0.0(7.97tha^{-1})>0.06gha^{-1}(6.14tha^{-1})>0.09gha^{-1}(3.67tha^{-1})$.While treatment of $1.20gha^{-1}(2.45tha^{-1})>1.50gha^{-1}(2.20tha^{-1})$. The study revealed that $0.03gha^{-1}$ gave the best yield and the reduced yield in the other rates could be as a result of high content of the Ca and Mg of the wood ash (Table 3.1). According to Havlin *et al.,* (2006), liming soils to pH of 7.0 can reduce availability of P and K in soils because of the precipitation of Ca and Mg. Agbede,(2009) reported that pH of the soil should be kept at 6.0 -6.5 to avoid yield reductions.

3.5 Regression of Soil pH Versus Wood Ash Rate

The response curves showing the effect of wood ash rates on soil pH is shown in figure 3.1. The pH level increased linearly with increase in wood ash application rates and the magnitude of coefficient of determination in the estimated response curve were highly significant (R^2=0.978). Havlin *et al.,*(2006) reported that liming soils to pH of 7.0 can reduce the available P and K due to precipitation of Ca and Mg, and high content of Ca and Mg was observed in the study (Table 3.1 and 3.2) The order of abundance were calcium>potassium>magnesium>sodium.

3.6 Regression of Exchangeable Acidity versus Wood Ash Rate

The response curve showing the effect of different rates of wood ash on exchangeable acidity (EA) is shown in figure 3.2. The EA response decreased linearly with the rates of wood ash application and sharply reduced from 0.6 to 1.6.The magnitude of coefficient of determination of the estimated curve were highly significant with R^2 value of 0.976.The result revealed that the acidity level decreased beyond the recommended rate for these soil which is between 6 to 6.5 for vegetable crops (Abgede 2009).

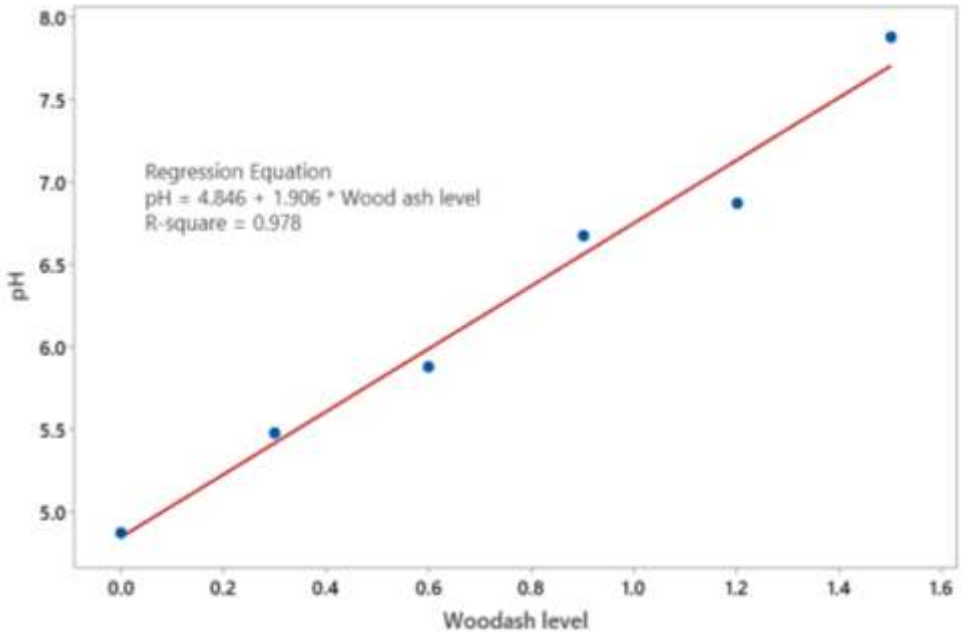

Figure 3.1: Regression of soil pH versus wood ash level

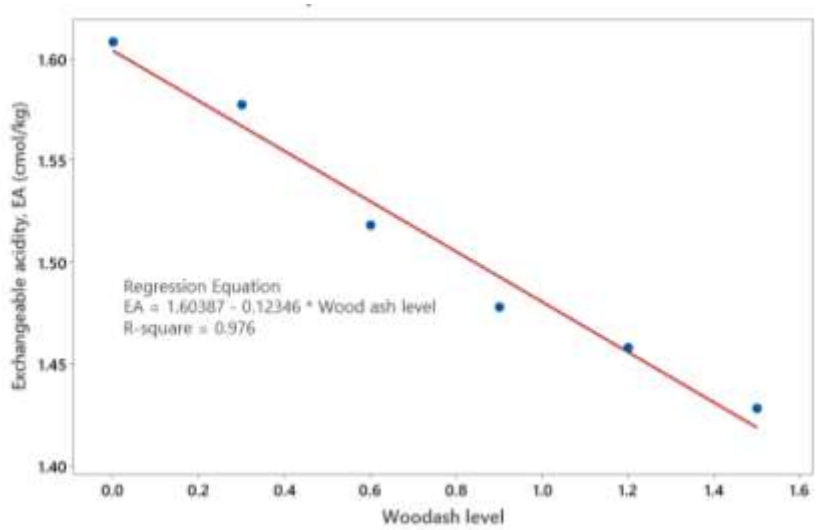

Figure 3.2: Regression of exchangeable acidity versus wood ash level

4.0 Conclusion and Recommendations

Results from this experiment indicated that the application of wood ash to the soil significantly increased soil nutrient contents such as N.P.K. Ca, Mg, ECEC, Base saturation and wood ash application also raised the soil pH from 4.87 in control to 7.89 at 1.5gha^{-1}.But wood ash decreased the exchangeable acidity (EA) with increased rate of wood ash application. Wood ash rate at 0.3gha^{-1} produced the best yield of tomatoes. The trend were 0.03gha^{-1}(9.95tha^{-1})>control (7.97tha^{-1})>0.06gha^{-1}(6.14tha^{-1})0.09gha^{-1}(3.67tha^{-1})>1.2gha^{-1}(2.45tha^{-1})>1.5gha^{-1}(2.20tha^{-1}). Therefore, based on the findings of the research 0.3tha^{-1} rate of wood ash is recommended in the soil for the production of tomatoes.

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