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IMPACT OF INTEGRATED NUTRIENT MANAGEMENT ON THE PHYSICO-CHEMICAL CHARACTERISTICS AND AGRONOMIC EFFICIENCY OF A COCOYAM- GROWN SOIL IN UMUDIKE, SOUTHEASTERN NIGERIA

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ABSTRACT

A 3-year field experiment was conducted from 2015 through 2017 cropping seasons at the Forestry Research Institute of Nigeria, Eastern Research Station, Umuahia to assess the impact of integrated nutrient management on the physical/chemical properties and agronomic efficiency of a cocoyam-grown soil environment. This experiment was fitted in a 3 x 3 factorial arrangement in randomized complete block design (RCBD) in which poultry manure formed Factor A with three levels (0, 5, 10 t/ ha) while NPK 20:10:10 fertilizer formed Factor B with three levels (0, 300, 600 kg/ha). There were a total of 9 treatment combinations with three replicates. Integrated plant nutrient management was applied through the method of band placement at 8 weeks after planting and after earthen up.Field data were taken on physical and chemical properties of the soil as well as cocoyam yield traits. The data were analyzed using analysis of variance (ANOVA) techniques for a 3 x 3 factorial in randomized complete block design (RCBD) according to the procedure described by Obi (2001). Fisher`s least significant difference (F-LSD) was applied to detect significant difference between two means at 0.05 % probability. The results of the experiment showed that application of integrated plant nutrient management significantly improved (P≤0.05) the agronomic efficiency, physical and chemical characteristics of the soil except base saturation.

Keywords: Agronomic efficiency, soil amendments, cocoyam, soil properties

INTRODUCTION

Cocoyams are edible aroids grown primarily for corms and cormels. They belong to the family *Araceae*, which has 110 genera of which *Colocasia esculenta, Xanthosoma sagittifolium, Amorphophalluspaeoniifolius, Alocasiamacrorrhiza*and *Cyrtospermamerkusii*are the most important and with about 2000 species (O`Hair, 1984). Cocoyams are used for both taro (*Colocasia esculenta*) and tannia (*Xanthosoma sogittifolium*) while otheredible aroids of less economic importance including *Alocasia*, *Amorphophallus* and *Cyrtosperma* are cultivated locally to form important food crops in parts of India, Southeast Asia and Pacific Islands (O`Hair, 1984; Pulseglove, 1979; Rubatzky and Yamagushi, 1997). Taro [*Colocasia esculenta (L.*)] is believed to have originated from South – East Asia while tannia [*Xanthosoma sagittifolium* (L.)] is indigenous to tropical America and West Indies (Uguru, 2011).

Cocoyam is one of the four most important staple foods in Nigeria, ranking third after yam and cassava, the fourth being sweet potato (Knipsheer and Wilson, 1980). It is the fourteenth most consumed vegetable worldwide and comprises the diet of 300 million people (Brown, 1998). It is commonly grown for the corms and cormels, although the leaves, petiole and flowers are also eaten as vegetables in soup during the vegetable – lean periods (Ezedinma, 1987). The corms and cormels can be processed into food paste called "*fufu"* or "*akpu"* (Ezedinma, 1987). The corms and cormels can be processed into chips called "*achicha"* and cooked with pigeon peas (*Cajanuscajan)* in Enugu State. The cormels of tannia are mostly cooked with common beans (*Phaseoluslunatus)* as porridge. The cormels are also cooked and eaten with special palm oil called "*Ngu"* (i.e. palm oil + water + potassium carbonate) in Afikpo South of Ebonyi State. Some varieties of taro such as "*Odogolo", "Nachi"* and "*Nworoko"* are used for soup thickening (Ogbonna and Orji, 2013).

The integrated plant nutrient management (IPNM) involves the maintenance of soil fertility to increase crop growth and yield through proper blending of both organic and inorganic manures considered appropriate for each cropping system and farming situation in its ecological and socio- economic realities (Roy *et al.*, 1992).The use of integrated plant nutrient management (IPNM) and inorganic fertilizers in cocoyam production is not yet common among the resource poor famers. They rely more on farmyard manure and household wastes which are found at their disposal. The amounts of the fertilizing materials available may not be enough for large scale production. Plants take nutrients mostly from the soil. It is also known that the optimal growth of plants is not only caused by the total amount of nutrients in the soil but also influenced by physico-chemical-biological properties of soil such as: soil texture, organic matter, cation exchange capacity, pH, electrical conductivity and activity of soil microbes. Chemical fertilizers is a beneficial input to obtain higher crop yield, but high rate of chemical fertilizers is characterized with reduction in soil properties and crop yields over time, while the organic fertilizer, such as cow manure has positive effects in maintaining the soil properties (Bell and Dell, 2008; Hepperly*et al*., 2009).Manure also is a good source of plant nutrients and improves soil structure (Mahmoodabadi*et al*., 2010). Moreover, Ould-Ahmed *et al*. (2010) reported that manure is an efficient compound for sandy soil with saline water irrigation. Hence, an integrated use of inorganic fertilizers with organic fertilizers; cow manure is a sustainable methods for efficient nutrient usage which increases efficiency of the chemical fertilizers and also can improve the properties of soil (Schoebitz and Vidal, 2016). The application of organic materials will improve physical, chemical and biological soil properties, while inorganic materials will improve the chemical soil properties, such as sufficing the supply of macro and micro essential nutrients to meet crop needs (Prasetyo*et al*., 2013). Application of synthetic fertilizers to increase crop production is conventional, but their long term use affects soil health (Hota*et al*., 2014).

It is universally known that application of inorganic manure can result in degradation of soil structure, increment of soil salinity and acidification as well as impediment of soil water percolation due to formation of crust on topsoil. At present, there is no documentation on the effect of integrated plant nutrient management onphysico-chemical characteristics of sandy loam of Umudike. Hence, this study was undertaken to assess the impact of integrated plant nutrient management on cocoyam – grown soil environment in Umudike, Abia State.

MATERIALS AND METHODS

The field research was conducted at the Forestry Research Institute of Nigeria, Eastern Research Station, Umuahia. The site lies on a longitude 07° 31´ E and latitude 05° 31´ N with altitude 149 m (high part) and a longitude 07° 31´ E and latitude 05° 31´ N with altitude 145 m (low part) above sea level (GPS). The annual rainfall is between 1500 and 1900 mm per annum with temperature ranges between 27 and 30 °C. It has a relative humidity ranging between 60 and 70 %.A piece of land with a dimension of 40.50 x 11 m was cleared with a matchet and slash burnt to ash because it was a fallow land for almost seven years. The land was prepared into plots of beds manually with hoe.Cormels with equal size (an average weight of 17.5 g) were planted at a spacing of 0.50 x 1.0 m (Uguru, 2011; Shiyam*et al.,* 2007). Each plot measured 4 x 3 m in dimension with net plots of 2.5 m^2. The distance between and within two plots was 1.0 and 0.50 m, respectively. All planting operations took place between 14^{th} and 16^{th} June for each farming season and harvesting was done in February in the following season. That is, eight months after planting. Weeding was done at four weeks interval starting from four weeks after planting (WAP) because the land was heavily weed infested. This experiment was laid out in a 3 x 3 factorial in randomized complete block design (RCBD) in which poultry manure formed Factor A with three levels (0, 5, 10 t/ ha) while NPK 20:10:10 fertilizer formed Factor B with three levels (0, 300, 600 kg/ha). There were a total of 9 treatment combinations with three replicates.Integrated plant nutrient management was applied through the method of band placement at 8 weeks after planting and after earthen up.Soil samples were collected prior to planting from different locations at the experimental site at the depth of 0-20 cm with a soil auger between 2015 and 2017 cropping seasons. The samples were properly mixed to get a composite sample from which a sub-sample was taken for laboratory analysis to determine the physical and chemical properties of the soil. The organic manures were also subjected to laboratory analysis to determine their nutrient composition. Soil samples were also collected from each plot of the nine treatment plots across the three replications and taken to laboratory for analysis at the end of the 2017 experiments to determine the physical and chemical characteristics of the site in order to assess the impact of the treatments on soil environment. The augured topsoil samples were air-dried and sieved with 2 mm sieve. Soil fractions sieved through a 2 mm mesh from individual samples were then analyzed using the following methods. Particle size distribution was measured by the hydrometer method as described by Gee and Bauder (1986). Soil pH was measured in a 1:2.5 (soil: 0.1M KCl) suspensions, while exchangeable acidity was measured using the method of McLean (1996). The soil organic carbon was determined by Nelson and Sommers methods (1982). Total nitrogen was determined by semi-micro kjeldah digestion method using sulphuric acid and $CuSO_4$ and Na_2SO_4 catalyst mixture as described by Thomas (1982). Sodium and potassium were determined from ammonium acetate leachate using the auto-electric flame photometer. Calcium and Magnesium were determined using the complex meter titration method as described by Thomas (1982). Cation exchange capacity (CEC) was determined by the method described by Thomas (1982). The available phosphorus was determined by the Bray II method described by Bray and Kurtz (1945). Base saturation was determined by calculation as the percentage ratio of total exchangeable bases (TEB) to effective cation exchange capacity (ECEC), using the procedure described by Umeh and Ogbuagu (2010). That is, % BS = TEB x 100/CEC.Agronomic efficiency was calculated with the following model: Agronomic efficiency:

$$\frac{\text{Treatment yield} - \text{control yield}}{\text{Quantity of applied soil amendment}} \times 100\ \%$$

The daily weather conditions on rainfall, temperature, sunshine hours, solar radiation and relative humidity of the location of the experiment were collected and recorded.Field data were taken on physical and chemical properties of the soil as well as cocoyam yield traits. The data were analyzed using analysis of variance (ANOVA) techniques for a 3 x 3 factorial in randomized complete block design (RCBD) according to the procedure described by Obi (2001). Fisher`s least significant difference (F-LSD) was applied to detect significant difference between two means at 0.05 % probability.

RESULTS AND DISCUSSION

Table 1 showed that 2015 cropping season had the highest value of minimum temperature (22.78 °C) while the least and maximum values were obtained in 2016. In the same vein, the highest annual rainfall (2189.50 mm) and mean relative humidity (73.20 %) were recorded in 2017. The least annual rainfall and relative humidity were recorded in 2016 and 2015, respectively.

According to the rating of soil minerals by Ufot (2012), the goat and poultry manures were strongly and very strongly alkaline, respectively (Table 2). This implies that both sources of manure have high potentialities of neutralizing acidic soils (Ultisols). Poultry and goat manures contained 832.0 g and 305.0 g of organic matter, respectively whereas total nitrogen of 2.5 and 5.3 grammes were contained in poultry and goat manures, respectively.

Table 3 showed the soil physical chemical characteristics of the soil in pre-planting soil sampling analyses for 2015, 2016 and 2017 cropping seasons. The texture of the location was sandy loam and moderately acidic in 2015, 2016 and 2017 cropping seasons. The value of organic matter was low in 2016 and available phosphorus within the three years were high. Total nitrogen was low in 2015 but high in 2016 and 2017 while in the three seasons, exchangeable potassium calcium, magnesium and exchangeable cation capacity (CEC) were low in the three seasons according to Udoh and Ndon (2016).

Table 1: Meteorological data of the experiment site at Umudike, Nigeria

	Months											
Meteorological factors	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Total**	**Mean**
2015												
Min. Temp (^{0}C)	24	23	23	22	22	23	22	23	23	22.9	227.90	22.79
Max. Temp (^{0}C)	31	29	29	28	28	30	28	30	31	29.50	293.50	29.35
Monthly Rainfall (mm)	13.0	89.7	310.9	361.2	302.7	176.3	361.6	206.1	49.70	0.00	1871.20	187.12
Relative Humidity (%)	67	70	72	74	78	68	76	66	62	35.00	668.00	66.80
2016												
Min. Temp (^{0}C)	23	22	22	20	20	21	21	20	21	23.6	213.60	21.36
Max. Temp (^{0}C)	33	32	32	32	31	33	31	32	33	32.6	291.60	29.16
Monthly Rainfall (mm)	88.3	169.9	202.8	164.2	231.1	282.5	304.0	205.8	150.2	4.10	1803.90	180.39
Relative Humidity (%)	67.0	70.0	76.0	78.0	80.0	68	79	66.0	64.0	51.3	699.30	69.93
2017												
Min. Temp (^{0}C)	23	22	22	21	21	23	21	22	22	23	219.00	21.90
Max. Temp (^{0}C)	32	31	30	30	29	31	29	30	31	33	306.00	30.60
Monthly Rainfall (mm)	12.2	88.8	316.8	368.0	402.6	264.1	392.4	277.0	62.0	5.6	2189.50	218.95
Relative Humidity (%)	69	70.0	71	80	80	85	82	70	65	60	732.00	73.20

Source: National Root Crop Research Institute (NRCRI), Umudike Meteorological Station.

Table 2: **Chemical properties of organic manure**

Parameters	Poultry manure	Goat manure
pH	9.40	86.00
Organic carbon (g/kg)	432.60	177.70
Organic matter (g/kg)	832.00	305.00
Total nitrogen (g/kg)	2.50	5.30
Calcium (g/kg)	38.00	40.00
Magnesium (g/kg)	23.00	33.70
Potassium (g/kg)	46.00	101.50
Sodium (g/kg)	16.00	23.70
Phosphorus (g/kg)	83.00	178.00

Source: NRCRI Soil Laboratory

Table 3:Physico-chemical properties of the experimental site before planting

Parameters	**2015**	**2016**	**2017**
Sand (%)	67.80	64.80	60.20
Silt (%)	11.40	11.80	12.30
Clay (%)	20.80	23.40	24.60
Texture	SL	SL	SL
pH ($H_2$$^{O)}$	5.90	5.80	5.60
Organic carbon (g/kg)	10.2	15.6	16.0
Organic matter (g/kg)	17.60	26.80	26.00
Available phosphorus (mg/kg)	39.60	68.20	60.80
Total nitrogen (g/kg)	)0	2.50	2.00
Exchangeable calcium (cmolkg)	)0	4.40	4.20
Exchangeable magnesium (cmol/kg)	1.60	1.20	1.25
Exchangeable potassium (cmol/kg)	0.12	0.19	0.20
Exchangeable sodium (cmol/kg)	0.35	0.21	0.18
Exchangeable acidity (cmol/kg)	1.12	1.20	1.18
Exchangeable CEC (cmol/kg	7.19	7.20	7.22
Base saturation (%)	84.42	83.33	80.15

SOURCE: NRCRI, UMUDIKE

Data on Table 4 indicated the overall effects of different sources of soil amendments on the physical and chemical properties of the site at the end of the three-year planting. The results revealed that there was no significant effect of integrated nutrient management on soil texture because it takes several decades for transcending of a particular textural class to another resulting from soil weathering. There were variations on soil pH range from very moderately to slightly acidic plots due to the different sources of amendments (Table 4), but more acidic compared to 2015 and 2016 pH ranges as described by Ufot (2012) except the plots that received the following treatments: 300 kg NPK + 5 tonnes of poultry manure/ha, 600 kg NPK + zero poultry manure which could be traceable to acidifying effect of inorganic fertilizer as a potential source of soil acidification which agreed with of the result of Nwite*et al*.(2016). The plot treated with poultry manure exhibited very low amount of organic matter (1.94 %) in 2016 and 2017 but little higher than that of 2015.However, a very high amount of organic matter (5.03 %) with 2.34 % carbon was received from the plot treated with 300 kg NPK + 5 t PM/ha and 600 kg NPK + 5 t PM/ha whereas the least percent was observed in the plots that did not receive any soil amendment. This phenomenon was traced to be the very high content of organic matter of poultry manure initially applied to the soil. This result agreed with the report of Nwite*et al*.(2016).Application of integrated plant nutrient management (300 kg + 5 t/ha) significantly increased ($P \leq 0.05$) available phosphorus (64.10 mg/kg) which was followed by the application of 600 kg NPK +5 t pm/ha relative to control. This result was attributable to the increased pH in the soil due to the application of integrated nutrient management which liberated fixed P at the sorption complex. This result is in agreement with the results of Ayoola (2009) and Nwite*et al*. (2016).In the same vein, integrated nutrient management application (300 kg NPK + 5 t pm/ha and 600 kg

Table 4: Effect of poultry manure, NPK fertilizer rates, spacing and their interactions in 2017

SAMPLE	SAND (%)	SILT (%)	CLAY (%)	TEXTURE	pH (H_2O)	OC (g/kg)	OM (g/kg)	P $MgKg^{-1}$	N (%)	Ca	Mg	K	Na	EA	ECEC	% BS
										Cmol kg^{-1}						
0F 0M	58.95	14.98	25.29	SL	5.87	9.60	13.70	32.70	0.18	4.08	2.91	0.22	0.15	0.50	7.94	97.53
0F 5M	62.84	17.51	16.93	SL	5.63	13.40	23.20	28.86	0.12	3.33	2.08	0.17	0.12	0.42	5.86	93.15
0F 10M	65.76	18.48	13.03	SL	5.97	11.80	19.40	26.01	0.10	4.58	2.91	0.23	0.16	0.67	8.28	92.24
1F 0M	66.73	15.56	14.98	SL	5.62	18.20	31.40	40.16	0.15	5.41	3.75	0.19	0.20	0.50	10.05	94.98
1F 5M	66.73	15.56	14.96	SL	6.39	23.40	50.30	64.10	0.17	6.24	2.50	0.22	0.19	0.58	9.40	94.00
1F 10M	64.78	16.45	16.93	SL	5.21	17.00	29.10	26.30	0.12	2.50	1.25	0.18	0.09	0.75	4.78	84.30
2F 0M	68.67	18.48	10.12	SL	5.15	16.70	28.80	36.39	0.15	5.83	2.91	0.30	0.19	0.50	9.45	94.86
2F 5M	64.78	16.89	14.96	SL	5.72	23.40	50.30	50.80	0.20	4.16	2.92	0.21	0.08	0.67	7.87	91.68
2F 10M	68.67	15.65	13.40	SL	5.92	17.80	29.50	41.82	0.19	4.18	2.50	0.21	0.18	0.58	7.46	92.36
F-LSD(0.05)	6.08	1.67	1.56		0.58	0.22	0.38	4.42	0.02	0.43	0.26	0.02	0.02	0.06	0.78	NS

KEY: 0F0M= Control; 0F5M= 0 Kg NPK/ha + 5 t PM/ha; 0F10M= 0 Kg NPK/ha + 10 t PM/ha; 1F0M= 300 Kg NPK/ha + 0 t PM/ha; 1F5M= 300 Kg NPK /ha+ 5 t PM/ha; 1F10M= 300 Kg NPK /ha+ 10 t PM/ha; 2F0M= 600 Kg NPK /ha+ 0 t PM/ha; 2F5M= 600 Kg NPK /ha+ 5 t PM/ha; 2F10M= 600 Kg NPK /ha+ 10 t PM/ha

NPK + 10 t pm/ha) significantly increased the nitrogen content of the soil. This increment was due to the mineralization pattern of the applied integrated nutrient management. This result is similar to the results of Singh *et al*. (2002) and Hota*et al.* (2014). Also, application of integrated nutrient management significantly increased calcium, magnesium, potassium, sodium, exchangeable acidity and effective cation exchangeable capacity contents of the soil. Significant amount of calcium (6.24 cmol/kg) and magnesium (2.92 cmol/kg) was observed in the plots where integrated nutrient management was applied which agreed with the results of Adediran*et al*. (1999) who reported that mineral fertilizer facilitates the decomposition and mineralization of organic manure whenever they are applied together. However, the application of 600 kg/ha NPK alone (2F0M)) significantly increased the quantity of potassium in the soil relative to control. This significant increment was attributed to the applied NPK fertilizer. This result is similar to the report of Prasetyo*et al.*(2013) and Hota*et al*. (2014) who asserted that application of synthetic fertilizer provides both macro and micronutrients to meet crop needs , although its long term use produces harmful effects on soil environment. Also, a significant value (0.75 cmol/kg) of exchangeable acidity was recorded in the plots treated with integrated nutrient management (300 kg NPK + 10 t pm/ha) compared to where there was no soil amendment whereas the least significant reduction on exchangeable acidity (EA) was observed on the plots treated with 5 tonnes of poultry manure per hectare. This significant increase on EA was due to the immobilization of the nutrients released from the integrated nutrient management by soil microorganisms leaving a preponderance of H^+ which increased the soil acidity. This result disagreed with the result of Nwite*et al*. (2016) who recorded significant increase on exchangeable acidity (EA) from control and plots treated with inorganic manure. More so, effective cation exchange capacity (ECEC) was significantly improved by the application of 300 kg NPK/ha which was followed by 600 kgNPK/ha while the least value was observed on the plots where integrated nutrient management (300 kg NPK + 10 t pm) was applied. This significant improvement on the ECECby the application synthetic fertilizer was due to the applied NPK fertilizer which has a higher and faster mineralization characteristic at the sorption complex compared to integrated nutrient management which requires a facilitator (synthetic fertilizer) for decomposition and mineralization of soil nutrients. This result disagreed with the reports of Agboola (1998) who observed significant increase on ECECby combined application of organic and inorganic manures.However, percentage basic saturation was not affected by the combined application of NPK fertilizer and poultry manure. Table 5 showed that there were non-significant differences of main effect of NPK fertilizer rates on agronomic efficiency between 2015 and 2016 except 2017 cropping season. In 2017, application of 300 kg NPK/ha significantly increased the agronomic efficiency (58.33 %) compared to other rates. This implies that it was better and economical to apply 300 kg/ha than 600 kg/ha. Application of poultry manure did not significantly affect agronomic efficiency. This means that the applied poultry manure was good for nothing as it was as good as the control because they were statistically the same. This non-significant effect of poultry manure might be due to nutrient immobilization by soil microorganisms. More so, a combined application of NPK fertilizer and poultry manure significantly improved agronomic efficiency in 2015 and 2017 in the plots treated with 300 kg NPK + 0 poultry manure in 2015 and 2017., but non-significantly different in 2016 cropping season. Although application of 600 kg/ha also significantly increased it together with 300 kg/ha, but its agronomic efficiency (72.67 %) was relatively lower than that of 300 kg application rate (91.00 %). This implies that sole application of NPK fertilizer was economically better in relation to its combination with poultry manure.

NPK fertilizer rates	2015 Cropping Season	2016 Cropping Season	2017 Cropping Season
0 kg/ha	---------------	------------	-----------
300 kg/ha	37.00	5.33	58.33*
600 kg/ha	23.83	4.50	40.17
F-LSD(0.05)	NS	NS	12.50
Manure rates			
0 t/ha	--------------------	---------------------	-----------------------
5 t/ha	0.66	0.58	-1.12
10 t/ha	0.75	0.33	0.25
F-LSD(0.05)	NS	NS	NS
Fertilizer x Manure Interaction			
0 x 0	------------	---------------	------------
0 x 5	0.22	0.86	1.46
0 x 10	0.97	- 0.13	1.89
300 x 0	70.00*	21.00	91.00*
300 x 5	3.28	0.87	3.92
300 x 10	2.22	0.21	2.95
600 x 0	45.83	21.00	72.67*
600 x 5	3.57	1.54	8.20
600 x 10	2.69	0.76	2.74
F-LSD(0.05)	50 %	NS	50 %

Table 5: Effect of integrated nutrient management on agronomic efficiency

CONCLUSION

The results of this research indicated that integrated nutrient management application significantly affected the physical and chemical properties as well as the agronomic efficiency of the cocoyam-grown soil environment of Umudike.

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