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Soil nutrient status and yield of waterleaf (*Talinum triangulare* Jacq) as influenced by rates of organomineral fertilizer in a rainforest Ultisol, Nigeria

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Abstract
Field experiment was conducted at the University of Calabar Teaching and Research Farm, Calabar in 2014 and 2015 planting seasons to evaluate the effect of different rates of organomineral fertilizer on soil properties, growth and yield of waterleaf in a degraded rainforest Ultisol in Southeastern Nigeria. Four rates of organomineral fertilizer (6, 8, 10 and 12 t/ha) and a control (no amendment) were laid out in a randomized complete block design (RCBD) with three replications. Results obtained showed that the application of different rates of organomineral fertilizer significantly increased ($P < 0.05$) soil pH, available phosphorus, basic nutrients (Ca, Mg and K), exchangeable acidity and base saturation status of the soil compared to control. There were significant differences ($P < 0.05$) among rates of application in plant height, number of leaves, number of branches, stem girth and fresh yield of waterleaf. Application of amendment irrespective of the rate of application enhanced waterleaf growth and yields more than the control. The fresh yield of waterleaf was significantly ($P < 0.05$) increased at all the growth stages measured (4, 7 and 10 weeks after planting (WAP)) as a result of the different rates of the amendment applied compared to the control. The mean fresh yields of 20.8, 24.6 and 24.9 t//ha obtained from plots treated with 12 t/ha of organomineral fertilizer at 4, 7 and 10 WAP, respectively were not significantly higher than the respective yields of 20.6, 23.8 and 23.7 t/ha obtained from 10 t/ha treatment. Therefore, the application of 10 t/ha of organomineral fertilizer is more appropriate for optimum production of waterleaf in a Rainforest Ultisol of Southeastern Nigeria.

Keywords: Organomineral fertilizer, soil properties, Ultisol, waterleaf, yield

1. Introduction

Waterleaf (*T. triangulare* Jacq), a leafy vegetable crop, is an erect perennial herb with swollen roots, and obtuse- angular hairless and succulent stems that can grow to about 30-60 cm tall and has branches. It is an all-season vegetable that is extensively grown in many countries in Asia, South America and West Africa. In Nigeria, it is widely cultivated and consumed in the Southern part, particularly in Cross River and Akwa Ibom States [1]. The demand for waterleaf is high in these states, and it is therefore a major source of income for farmers. Its high demands are attributed to its nutrient value and importance as a "softener" when cooking the common fibrous leafy vegetables such as Afang (*Gnetum africana*), Atama (*Heinsia crinata*) and Editan (*Lasienthera bulchozioanum*). It is also cooked with green amaranth (*Amaranthus curentus*) and fluted pumpkin (*Telfairia occendentalis*). Nutritionally, waterleaf has been proven to be high in crude protein (22.1%), ash (3.40%) and crude fibre (1.11%) [2]. It has some medicinal values in human and acts as green forage for rabbit feed management. In addition, waterleaf production provides a complementary source of income to small scale faming households [3].

Waterleaf is a shade loving leafy vegetable grown throughout the year, it can also grow in fully exposed localities, but the plants remain small. Growth is most profuse when water content of the soil is close to field capacity. The pH range for optimum growth and yield of waterleaf is 6.1-7.8 [4] and is adapted to a wide range of soil conditions. Waterleaf is short duration crop which is due for harvest between 35-45 days after planting. The increasing demand for waterleaf due to urbanization has therefore pushed farmers into small and medium scale production of waterleaf. Consequently, to obtain optimum yield, organic fertilizers are being developed by farmers from farm and city wastes for vegetable production.

The utilization of organic manure by vegetable producers may have an additional advantage of ensuring crop quality and environmental safety compared to chemical fertilizer.

Organomineral fertilizers (OMF) in which organic wastes are fortified with inorganic N or NP fertilizers are being utilized by crop farmers. Organomineral fertilizers are made up of natural components enriched and complemented with chemical elements for fast action. The organic substances act as added enrichment for the humus content of the soil. Combined application of organic manure and mineral fertilizers often goes with such additional advantages as buffering the soil against undesirable acidification and increasing the availability of nutrients [5, 6]. The blending of organic manure with mineral fertilizer may help to increase the productivity of crops on fragile soil by reducing the problem of nutrient losses via leaching. The complementary application of organic and inorganic fertilizers to arable soil has been viewed as excellent way to have safe environment, recycle nutrients and organic matter that can support crop production and improve soil quality [5-7]. Therefore the objective of the study was to evaluate the effect of different rates of organomineral fertilizer on soil properties, growth and yield of waterleaf in a degraded rainforest Ultisol in Southeastern Nigeria.

2. Material and methods

2.1 Description of the Experimental Site

The study was carried out at the Teaching and Research Farm of the University of Calabar, Calabar, and Southeast Nigeria. Calabar is located within the humid tropical region and it lies between latitude 5° 32’ and 4° 27’ N and longitude 7° 15’ and 9° 28’ E in Nigeria. The annual rainfall ranges from 2000 mm to 3500 mm, mean temperature ranges from 23^{0c} to 90^{0c} while mean relative humidity is 60 % to 90 % (University of Calabar Meteorological Unit). The town is characterized by a bimodal rainfall pattern with a long rainy season (March- July) and a short rainy season from September to early November after a very short dry spell in late August. The soil is classified as an Ultisol by the USDA system of classification [8].

2.2 Land preparation, experimental design and treatments

The experimental site was cleared manually, tilled and plots measuring 2 m × 1.5 m made. An alley of 1.2 m was left between blocks and 0.60 m between plots. The experiment was laid out in a randomized complete block design with three replications. The treatments comprised of five levels of organomineral fertilizer (0, 6, 8, 10 and 12 t/ha) with the 0 t/ha serving as control. The various rates of organomineral fertilizer were applied three days before planting by broadcasting with incorporation method.

2.3 Field studies

Waterleaf was planted manually at a spacing of 5 cm × 5 cm using stem cuttings of 10 cm length with leaves still attached, giving a plant population of 4, 000, 000 plants/ha. Weeding was done manually by hand pulling within the plots and using hoe to weed around the plots. Twenty plants were randomly selected, tagged and used in growth measurements. Growth parameters measured were plant height, number of leaves per plant, number of branches per plant, leaf area and stem girth. These parameters were assessed after 4 weeks of planting (WAP) and subsequently at three weeks intervals. Weights of freshly harvested waterleaf were taken from an area of 50 cm × 50 cm within each experimental plot at 4, 7 and 10 WAP. At the end of the experiment, composite soil samples were taken per plot for chemical analysis.

2.4 Soil sampling and processing

Soil samples were taken from the experimental site before and after experiment using soil auger at a depth of 0 to15 cm. About 6-8 sample points were taken from each block, mixed thoroughly to make a composite sample before commencement of experiment, while one composite soil sample was taken per plot after the experiment for laboratory analysis. The soil samples were air-dried, ground and sieved with 2 mm sieve to remove materials greater than 2 mm in diameter before using it for analysis.

2.5 Laboratory analysis

The organomineral fertilizer and soil samples collected were analyzed in the laboratory using standard procedures as described by [9]: Particle size distribution was determined by the Bouyoucous hydrometer method, using sodium hexametaphosphate as a dispersant. Soil pH was determined using a ratio of 1:2 in soil-water medium and read with a digital pH meter. Organic carbon content was determined by Walkley-Black dichromate oxidation method. Organic matter was obtained by multiplying total carbon by a factor of 1.724. Total nitrogen (N) was determined by the micro-kjeldahl method. Available phosphorus (P) was extracted by the Bray 1 extraction method, and the content of P was determined colorimetrically using a Technico AAII auto analyser (Technico, Oakland, Calif). Determination of exchangeable bases was by neutral ammonium acetate extraction and read with an atomic absorption spectrophotometer (AAS). Exchangeable acidity was determined by the 1 N potassium chloride (KCl) extraction method and titrated with 1 M sodium hydroxide (NAOH) using phenolphthalein as an indicator. The effective cation exchange capacity (ECEC) was the summation of total exchangeable bases and exchangeable acidity. Base saturation percentage was calculated by dividing the sum of exchangeable bases by ECEC and multiplied by 100.

2.6 Data analysis

Data collected were screened for normality using the data validation and data exploration modules of SPSS version 21, constant variables were removed. Then analysis of variance (ANOVA) was done on the data using the two-way ANOVA module for randomized complete block design using [10], according to the procedures outlined by [11]. Significant means were compared using Fisher's least significant difference (FLSD) using mean comparison module in GenStat [10] at 5 % level of probability.

3. Results and discussion

3.1 Properties of the soil and the organomineral fertilizer used for the study

The pre-cropping physical analysis showed that the soil used for the study was loamy sand in texture (Table 1a). The chemical properties of the soil used for the two year planting seasons were similar with a very strongly acid pH and low nutrient reserve especially nitrogen. As rated by [12], soils with less than 1.5 g/kg total nitrogen in humid tropical region is low. The low nitrogen level could be attributed to

the high rate of mineralization and subsequent high rate of leaching accompanied by heavy rainfalls which is usually associated with the rain forest zone of Southeastern Nigeria.
From the result of the chemical composition of the OMF (Table 1b), the fertilizer material indicated alkaline reaction (12.6) when tested in water slurry with 35.9 g/kg organic carbon, 22.7 g/kg total N, 97.0 mg/kg total P and 0.18 mg/kg total K indicating the potential of OMF to ameliorate soil acidity and improve the nutrient contents of soils.

3.2 Effects of rates of organomineral fertilizer on soil propertiies

The effects of the different rates of application of organomineral fertilizer on soil chemical properties are presented in Table 2. They were significant ($P < 0.05$) increases in soil pH, organic carbon, total nitrogen, available phosphorus, basic nutrients (Ca and Mg), exchangeable acidity, effective cation exchange capacity (ECEC) and base saturation status of the soil compared to control (without amendment) with the properties increasing with corresponding increase in the rate of application of the amendment. The highest pH value of 5.64 obtained from soil treated 12 t/ha OMF was significantly higher than those that received other OMF rates and control. These observations are in agreement with the findings of [13] who reported that increasing rates of organomineral fertilizer resulted in increasing values of soil pH, organic matter, total N, available P, Ca and ECEC. However, the values obtained for total nitrogen in the amended soils were still below the critical level of 1.5 g/kg N. This could be as a result of higher nutrient uptake by crops and/or loss through leaching [14]. Increase in available P content in the treated soils could be due to the organic amendment in the fertilizer which was observed to have also increased the amount of soluble organic matter thereby increasing the rate of desorption of phosphate, thus improving the available P content in the soil [15, 16].

Table 1a: Properties of the soil before treatment application

Parameter	Soil value	
	2014	2015
pH (H_2O)	4.5	4.6
Org. C (g/kg)	18.0	16.7
Total N (g/kg)	1.20	1.40
Av. P (mg/kg)	8.00	9.5
Exch. Ca (cmol/kg)	3.3	4.0
Exch. Mg (cmol/kg)	2.0	2.8
Exch. K (cmol/kg)	0.11	0.09
Exch. Na (cmol/kg)	0.09	0.07
Exch. H^+ (cmol/kg)	2.41	3.21
Exch. Al^{3+} (cmol/kg)	0.25	0.15
ECEC (cmol/kg)	8.16	10.32
Base saturation (%)	67.40	67.00
Sand (%)	82.0	83.0
Silt (%)	15.0	14.0
Clay (%)	3.0	3.0
Texture	Loamy sand	Loamy sand

Table 1b: Chemical composition of organomineral fertilizer (OMF)

Parameter	OMF value
pH (H_2O)	12.60
Org. C (g/kg)	35.9
Total N (g/kg)	22.7
Total P (mg/kg)	57.00
Total Ca (mg/kg)	5.60
Total Mg (mg/kg)	20.40
Total Na (mg/kg)	1.10
Total K (mg/kg)	0.18

Table 2: Effects of organomineral fertilizer (OMF) rates on soil chemical properties.

Treatments OMF (t/ha)	Soil pH (H_2O)	Org. C (g/kg)	Total N (g/kg)	Av. P (mg/kg)	Exchangeable cations (cmol/kg)				Exch. Acidity (cmol/kg)		ECEC (cmol/kg)	Base saturation (%)
					Ca	Mg	K	Na	Al^{3+}	H^+		
Control	4.30	10.0	0.90	15.42	1.17	0.73	0.06	0.06	1.79	1.17	4.98	40.56
6	5.13	11.43	1.00	19.25	2.20	2.20	0.07	0.06	1.47	1.62	7.62	59.45
8	5.17	15.50	1.00	19.42	2.33	2.27	0.07	0.06	1.47	0.91	7.11	66.53
10	5.33	18.60	1.05	20.64	2.80	2.60	0.08	0.07	1.35	0.86	7.76	71.52
12	5.64	18.73	1.08	31.00	5.92	2.67	0.09	0.07	1.12	0.84	10.71	82.00
FLSD(0.05)	0.24	2.40	0.10	6.13	0.32	0.13	NS	NS	0.47	0.19	2.03	8.21

3.3 Effect of rates of organomineral fertilizer on growth and yield of waterleaf

Table 3 shows significant increases in plant height and stem girth of waterleaf at different growth stages as influenced by the different rates of OMF applied. At 4, 7 and 10 weeks after planting (WAP), there were significant increases in plant height and stem girth by all the rates of application compared with the control. The biggest stem girth (3.02 cm) was obtained from plants treated with 12 t/ha of OMF at 7 WAP, though not significantly different from plants treated with 10 t/ha OMF (Table 3). Significant increases were observed as the rate of application of the amendments increased.
Number of leaves per waterleaf plant was significantly increased by all the treatments across all growth stages relative to control (Table 4), with the highest value (25.71) obtained from plants treated with 12 t/ha of OMF at 10 WAP. The highest number of branches (6.96) was also obtained from plants treated with 12 t/ha of OMF at 10 WAP and was not significantly more than the number of branches obtained by plants treated with 10 t/ha of OMF (6.90). Significant increases were also observed as the rate of application of the amendments increased.
The responses of waterleaf growth to fertilizer application in an *Ultisol* of Southeastern Nigeria have also been reported by [17, 18].
Fresh yield of waterleaf was significantly ($P \leq 0.05$) increased by all the rates of application of OMF at all growth stages compared with control (Table 5). The highest mean fresh yield of 20.8 t/ha obtained at 4 WAP from plants treated with 12 t/ha compost did not differ significantly ($P \geq 0.05$) from plants treated with 10 t/ha OMF (20.6 t/ha) treatments, but differed significantly from other rates and control. At 7 WAP, the highest mean fresh yield of 24.6 t/ha obtained from plants treated with 12 t/ha OMF was significantly higher than all other treatments except 10 t/ha

treatment (23.8 t/ha). At 10 WAP, the highest mean fresh yield of 24.9 t/ha was obtained from plants treated with 12 t/ha OMF and this was not significantly higher than the mean fresh yield of 23.8 t/ha obtained from 10 t/ha treated plants but was significantly higher than all other rates and control.

The yields obtained from this study were relatively lower than the yield (56.03 and 54.36 t/ha in 2009 and 2010, respectively) obtained by [17] that used 100 kg/ha of NPK + 3.75 t/ha of poultry manure in the cultivation of waterleaf in Akwa Ibom State, Nigeria but falls within the yield they obtained by the application of 5 t/ha of poultry manure (23.33 and 22.96 t/ha in 2009 and 2010, respectively). The disparity in yield could be accounted for by a number of factors, including the original status of the soil with respect to the nutrient elements, other edaphic factors and climatological variability. It could also be due to the fact that integrated use of organic and inorganic fertilizers promotes higher positive effect on microbial biomass and hence soil health [19]. However, [18] reported yield levels 17.86, 22.92 and 22.34 t/ha for waterleaf at 4, 7 and 10 WAP, respectively by using 8 t/ha cassava peels/ poultry manure – based compost in Cross River State, Nigeria. Best performance of *Amaranthus* has been reported by [6] from the combined use of organic pig manure and inorganic urea fertilizer. This means that there is always a proportional increase in all the parameters assessed when additional nutrients were applied to crops.

Table 3: The mean plant height and stem girth of waterleaf as influenced by organomineral fertilizer rates

OMF rates (t/ha)	Plant height (cm)			Stem girth (cm)		
	4 WAP	7 WAP	10 WAP	4 WAP	7 WAP	10 WAP
Control	9.30	9.70	6.61	1.35	1.14	1.14
6	12.11	14.5	11.28	1.85	2.27	2.49
8	14.70	16.7	14.68	1.86	2.58	2.62
10	18.10	18.70	15.10	1.92	2.91	2.98
12	17.82	18.84	15.66	2.05	3.02	3.00
FLSD (0.05)	2.42	1.53	3.20	0.14	0.65	0.30

Table 4: The mean number of leaves and number of branches per waterleaf plant as influenced by organomineral fertilizer rates

OMF rates (t/ha)	Number of leaves per plant			Number of branches per plant		
	4 WAP	7 WAP	10 WAP	4 WAP	7 WAP	10 WAP
Control	8.20	7.48	6.74	2.71	3.00	2.90
6	13.37	20.48	17.77	2.71	4.20	5.90
8	13.57	22.76	20.89	2.90	4.60	6.28
10--	13.81	24.23	23.50	3.65	6.30	6.90
12	13.90	25.50	25.71	3.67	6.30	6.96
FLSD (0.05)	2.12	2.5	3.23	NS	1.18	1.26

Table 5: The mean fresh yield of waterleaf as influenced by organomineral fertilizer rates

OMF rates (t/ha)	Fresh yield (t/ha) of waterleaf		
	4 WAP	7 WAP	10 WAP
Control	4.90	3.60	3.48
6	12.80	13.84	14.50
8	16.70	18.40	18.56
10	20.60	23.80	23.67
12	20.82	24.60	24.94
FLSD (0.05)	3.6	4.4	5.3

4. Conclusion

This study showed that waterleaf responded positively to the application of organomineral fertilizer (OMF) with the growth parameters enhanced and yield increased as the rates of application increased. However, there was no significant increase in fresh yield of waterleaf between plants treated with 10 t/ha and 12 t/ha OMF. The mean fresh yields of 20.8, 24.6 and 24.9 t//ha obtained from plots treated with 12 t/ha of organomineral fertilizer at 4, 7 and 10 WAP, respectively were not significantly higher than the respective yields of 20.6, 23.8 and 23.7 t/ha obtained from 10 t/ha treatment. Therefore, the application of 10 t/ha of organomineral fertilizer is more appropriate for optimum production of waterleaf in a Rainforest Ultisol of Southeastern Nigeria.

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