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Effects of Fertilizer Treatments on Soil Chemical Properties and Crop Yields in a Cassava-based Cropping System

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Abstract: A study was carried out to examine the effect of inorganic and organic fertilizers on soil chemical properties and crop yields in a cassava-based cropping system. The treatments were organic fertilizer -5 t/ha/year; inorganic fertilizer - 400 kg/ha NPK 15-15-15; inorganic + organic fertilizer - 200 kg/ha NPK 15-15-15 and 2.5 t/ha organic fertilizer and a control (no fertilizer). The crops planted were cassava, maize, melon and cowpea. The result showed that fertilizer treatments had no significant effects on soil pH after cropping for two years. The level of organic C decreased by about 17, 44, 47 and 59% under organic fertilizer, inorganic + organic fertilizer, no fertilizer and inorganic fertilizer respectively. Total N decreased in all the plots after cropping. Available P reduced from initial value of 4.72 mg/kg to 3.37 mg/kg where no fertilizer was added but increased by 8% and 9% under inorganic + organic and inorganic fertilizers. Exchangeable K decreased in all the plots irrespective of fertilizer type and the changes ranged between 25% under organic fertilizer and 53% under inorganic fertilizer treatment. Addition of Organic fertilizer increased Effective Cation Exchange Capacity (ECEC) by 16% while it reduced in all other plots. Though the yields of crops were increased by application of inorganic and organic fertilizers in this experiment but the changes in soil nutrient status after cropping have shown there might be need to increase the level of organic material added to sustain the fertility of the soil.

Key words: Cropping system, Organic fertilizer, inorganic fertilizer

INTRODUCTION

Many African soils show nutrient deficiency problems after only a short period of cultivation because of their nature as well as prevailing environmental conditions [19]. Farmers have sought to furnish additional nutrient by the application of compost, manures and chemical fertilizer so that the yields of crops will no longer be limited by the amount of plant nutrients that the natural system can supply [16]. It had been observed that inorganic (chemical) fertilizers are an essential component of any system in which the aim is to maintain good yield in the absence of sufficient organic, natural manure [19]. The use of mineral fertilizer alone has however not been helpful under intensive agriculture because it is often associated with reduced yield, soil acidity and nutrient imbalance [14]. The need to use renewable forms of energy has revived the use of organic fertilizers worldwide. Improvement of environmental conditions and public health as well as the need to reduce costs of fertilizing crops are also important reasons for advocating increased use of organic materials [20; 7]. The benefits derivable from the use of organic materials have however not been fully utilized in the humid tropics partly due to the huge quantities required in order to satisfy the nutritional needs of crops, transportation and handling costs which constitute a major constraint.

In the south western part of Nigeria, traditional farmers practice intercropping (a form of intensive cropping) with a wide range of crops consisting usually of a major crop and other minor crops. Crops like cassava, maize, yam and plantain are planted as major crops while melon, cowpea and vegetables are minor crops in various parts of the region [11]. The judicious management and conservation of the soil to guide against decreased crop yields under intensive cropping have become major areas of agronomic research [2]. Complementary use of organic manures and mineral fertilizers has been proved to be a sound soil fertility management strategy in many countries of the world [15]. High and sustained crop yield has been reported with judicious and balanced NPK fertilization combined with organic matter amendment [14]. Maintenance of the fertility status of the soil is also an important factor in order to obtain a stable and sustainable agro ecosystem. This study therefore aimed to examine changes in soil chemical properties and yields of crops under inorganic and organic fertilizers in a cassava-based cropping system.

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MATERIALS AND METHODS

Location: The experiments were conducted between 1996 and 1998 in the Teaching and Research farm of the University of Ibadan in the south western area of Nigeria. Ibadan lies on latitude $7^0$30'N and longitude $3^0$54'E with the annual rainfall ranging between 1000 and 1,600mm. The mean annual temperature ranged between 19.1^{0}C and 35.3^{0}C while the average relative humidity ranged from 69% to 79%. The soil of the experimental site belongs to the broad group Alfisol (Plinthic Tropudalf) [23].

The site had been cultivated to crops such as maize, cassava and legumes. Little or no fertilizer had been used in the area. The fallow periods have not been consistent but it was covered by both annual and perennial weeds such as *Euphorbia heterophylla, Chromolaena odorata, Panicum maximum* and *Mucuna Mucunoides* before the commencement of these studies.

Soil Sampling and analysis: Top soil samples (0-15cm depth) were taken from the experimental site before planting and at the end of the experiments. Twenty core samples collected randomly were mixed inside a plastic bucket and a composite sample was taken before first cropping. Composite samples were taken per plot at the end of the second year of cropping.

The soil samples were air-dried, crushed and sieved through a 2mm sieve. The samples were analyzed in the laboratory for some physical and chemical properties using the procedures as described in the International Institute of Tropical Agriculture (IITA) laboratory manual [10]. Particle size distribution was carried out by hydrometer method while soil pH was measured with the glass-electrode pH meter on 1:1 soil – solution mixture. The organic Carbon was determined by Walkey-Black method and the total N was by regular macro – kjeldahl method. Available P (mg kg-^{1}) was determined by the Bray 1 method while the exchangeable cations were extracted with 1NNH_4OAc solution. Calcium, Na and K were measured with the flame photometer and Mg was determined on the atomic absorption spectro - photometeter. Exchangeable acidity (H^+) of the soil was determined by titration method.

Effective cation exchange capacity (ECEC) was established as the sum of the exchangeable cations K, Na, Ca and Mg and H^+ expressed in c mo1 kg-^{1} of soil. The results of the analyses are shown in Table 1.

Experimental design and Treatments: The experiments were laid out in a randomized complete block design with three fertilizer types: organic fertilizer, inorganic fertilizer, inorganic + organic fertilizer and a control (no fertilizer). Inorganic fertilizer was supplied in the form of 400 kg/ha NPK 15-15-15 based on recommendations for cassava/maize/melon mixture [4,5].

Table 1: Initial chemical and physical characteristics of the soil at the experimental site.

pH(H_2O)	5.70
Total N (g kg^{-1})	1.80
Organic C (gkg^{-1})	17.50
Available P (mg kg-^{1})	4.72
Exchangeable K (cmolkg^{-1})	0.36
" Ca "	3.75
" Mg "	2.44
" Na "	0.57
" Acidity (H^+) "	0.12
ECEC "	7.24
Sand (gkg^{-1})	850.00
Silt "	74.00
Clay "	76.00

Table 2: Chemical composition of the organic fertilizer used.

N (%)	1.65
C (%)	34.5
P (%)	0.52
K (%)	0.91
Ca (%)	0.26
Mg (%)	0.25
Mn (mgkg^{-1})	0.32
Fe "	2.36
Zn "	0.96
Cu "	0.64

Organic fertilizer was a mixture of decomposed poultry manure and urban refuse (1:1) at the rate of 5 t/ha/year [21;4].

Inorganic + Organic fertilizer consisted of 200 kg/ha NPK 15-15-15 and 2.5 t/ha organic fertilizer (i.e. half of inorganic and organic fertilizers rates combined). Chemical composition of the organic fertilizer used is presented in Table 2. Organic fertilizer was applied a week before planting. It was uniformly spread on the plots and lightly worked into the soil with hoe. Inorganic fertilizer was applied 3 weeks after planting by ringing around maize plant.The plot size was 24 m^2.

Cultural Practices: Cassava variety TMS 30572, the most popular improved variety among local farmers was planted. The maize variety planted was DMR-LSR-W while a local variety of melon (egusi) was used. Ife-brown variety of cowpea was planted in the late season. Planting was done on the flat. The trial was conducted for two consecutive years. Cassava, maize and melon were planted at the same time in each year of experimentation. Cowpea was relayed into cassava at 18 weeks after planting when maize and melon had been harvested. Maize and melon were planted at a spacing of 1m x 1m at 2 plants/stand to achieve a plant population of 20,000 plants ha-^{1} for each of the crop. Plant population for cowpea was 55,555 plants ha-^{1} from a spacing of 0.6m x 0.6m with 2 plants per stand. Cassava was planted at a spacing of 1m x 1m to obtain a plant population of 10,000 plants ha-^{1} .The plots were weeded manually whenever necessary throughout the experimental period. Cowpea pests (insects) were controlled with Karate$^{(R)}$ (Lambda-cyhalothrin) at the rate of 800 m1/ha. Spraying was commenced 5 weeks after planting at 1 week interval until full pod formation.

Maize was harvested fresh at 12 weeks after planting and it was dried to 14% moisture content to get dry grain weight. Melon was harvested and processed at 5 months after planting. The seeds were sun dried and weighed. Ripe and dry pods of cowpea were picked as from the 10th week of planting to avoid shattering and weevil infestation. Cassava was harvested 12 months after planting.

Data analysis: Statistical analysis of data was done using analysis of variance (ANOVA) procedure and means were compared using Duncan's Multiple Range Tests (DMRT).

RESULTS AND DISCUSSIONS

Changes in soil nutrient status: Fertilizer treatments had no significant effects on soil pH after cropping for two years. The level of organic C decreased by 17, 44, 47 and 59% under organic fertilizer, inorganic + organic fertilizer, no fertilizer and inorganic fertilizer respectively (Table 3). The lowest reduction in organic C that occurred in the plot treated with organic fertilizer could be attributed to the fertilizer applied. This shows that the incorporation of organic fertilizer into the soil could be an efficient way of maintaining desired soil organic matter level. Total N decreased in all the plots after cropping but it decreased more under inorganic fertilizer alone because nutrients from this source were readily available compared to that from organic source. It has also been reported that N is taken up faster and therefore competed for under intercropping system [12]. The C/N ratio was highest where organic fertilizer was applied though it seems to be somehow stable in all the plots showing active mineralization. This could be attributed to the fact that crop residues were left on the field. The highest reduction in organic C and total N was observed from plots treated with inorganic fertilizer resulting from stimulated decomposition of soil organic matter and crop residue by the applied fertilizer which led to higher N mineralization. This could result to higher N uptake by crops and/or loss through leaching. Earlier workers had reported that continuous use of inorganic fertilizer alone brought about rapid deterioration of soil organic matter [1]. Reductions in organic C and total N were not as much under inorganic + organic fertilizer as in inorganic fertilizer plots showing that these nutrients were conserved better where a combination of inorganic and organic fertilizers was applied. Available P reduced from initial value of 4.72 mg/kg to 3.37 mg/kg where no fertilizer was added due to removal by crops without addition from external inputs. Increases of 8% and 9% were however observed under organic and organic + inorganic fertilizer treatments respectively (Table 3). The incorporation of manure and crop residues has been shown to increase the amount of soluble organic matter which are mainly organic acids that increase the rate of desorption of phosphate and thus improves the available P content in the soil [24]. Changes in available P were generally low in all the plots because P is relatively immobile and strongly adsorbed by soil particles [9]. Exchangeable K decreased in all the plots irrespective of fertilizer type and the changes ranged between 25% under organic fertilizer and 53% under inorganic fertilizer treatment (Table 4). Cassava which could be considered the major crop in the crop mixture has a medium to high external nutritional requirement for N and K [18]. The same author also noted that K was removed in largest quantity with harvested cassava followed by N but P removed was extremely low . It follows therefore that the combined demands of cassava and 2 or 3 companion crops for these nutrients would cause a steady decrease in the nutrients during the growing seasons.

Table 3: Changes in soil pH, organic C, total N and Av. P under different fertilizers.

	Soil pH (H_20)			Org. C g/kg			Tot. N g/kg			Av. P mg kg^{-1}		
	K	*L	M	K	*L	M	K	*L	M	K	*L	M
Organic	5.7	5.6a	-0.1	17.5	14.55a	-2.95	1.80	1.03b	-0.77	4.72	5.10a	-0.95
inorganic	5.7	5.5a	-0.2	17.5	7.19d	-10.31	1.80	0.82c	-0.98	4.72	3.77b	0.38
Org.+ inorg.	5.7	5.6a	-0.1	17.5	9.86b	-7.64	1.80	1.33a	-0.47	4.72	5.14a	0.42
No fertilizer	5.7	5.5a	-0.2	17.5	9.30c	-8.2	1.80	0.95b	-0.85	4.72	3.37b	-1.35

K= before cropping ; L= after cropping; M= difference
*values followed by the same letter in this column are not significant at P=0.05 (DMRT)

Table 4: Changes in Exchangeable K, Ca, Mg, Na and CEC under different fertilizers.

	Ex. K(cmolkg^{-1}			Ex. Ca(cmolkg^{-1}			Mg(cmolkg^{-1}			Na(cmolkg^{-1}			CEC		
	K	*L	M	K	L	M	K	*L	M	K	*L	M	K	*L	M
Organic	0.36	0.27a	-0.09	3.75	4.53a	0.78	2.44	2.94a	0.50	0.57	0.53a	-0.04	7.24	8.38a	1.14
Inorganic	0.36	0.17b	-0.19	3.75	2.71c	-1.04	2.44	1.77c	-0.67	0.57	0.39b	-0.18	7.24	5.15d	-2.09
Org.+ inorg.	0.36	0.26a	-0.10	3.75	3.51b	-0.24	2.44	2.28b	-0.16	0.57	0.39b	-0.18	7.24	6.55b	-0.69
No fertilizer	0.36	0.18b	-1.18	3.75	3.43b	-0.32	2.44	2.23b	-0.21	0.57	0.39b	-1.18	7.24	6.43c	-0.81

K= before cropping ; L= after cropping; M= difference
*values followed by the same letter in this column are not significant at P=0.05 (DMRT)

Table 5: Yield (t/ha) of crops as affected by fertilizer types.

Fertilizer	Maize	Melon	Cassava	Cowpea
Organic	1.34b	0.20a	8.51ab	0.41b
Inorganic	2.34a	0.23a	9.20ab	0.40b
Org.+ inorg.	2.14a	0.21a	9.98ab	0.46a
No fertilizer	1.14b	0.22a	7.33b	0.39b

Values followed by the same letter in this column are not significant at P=0.05 (DMRT)

Exchangeable Ca increased by about 21% in plots treated with organic fertilizer after cropping but it reduced in all other plots. Reduction in exchangeable Mg was more under inorganic fertilizer compared with any other treatment including the control. The values of Exchangeable Na were statistically the same after cropping under inorganic fertilizer and inorganic + organic and it reduced from the initial value by 32%. It however reduced by 7% under organic fertilizer (Table 4). Addition of organic fertilizer increased Effective Cation Exchange Capacity (ECEC) by 16% while it reduced in all other plots. It has been recorded that crops took up more nutrients when mineral fertilizer was added in what is known as 'luxury consumption' probably because nutrients from this source are readily available [8]. Iwueke [12] found that aggregate uptake of each nutrient was higher in the intercrop of cassava/maize/melon than in the sole crops suggesting that soil nutrient reserves would deplete faster under intercropping than sole cropping unless a commensurate fertilizer regime is maintained. It has been observed that addition of manure increased soil water holding capacity and this means that nutrient would be made available to crops where manure has been added to the soil [3]. The rate of depletion of ECEC was least where inorganic + organic was added showing that nutrients were conserved better than inorganic fertilizer treatment. Uphoof [22] encouraged the use of organic amendments since chemical fertilizers do not contribute much over time to soil quality.

Yield of Crops: Maize yields were statistically similar under inorganic and inorganic + organic fertilizer treatments while the lowest yield was from the control (no fertilizer) plot (Table 5). The yield of maize was highest under inorganic fertilizer treatment because nutrients are readily released from this source and maize, a short duration crop, being an aggressive feeder was able to utilize it for its growth and yield. Yields of maize got from organic fertilizer treatment was not different from that of the control plot and yields of melon were not significantly different under the various fertilizer treatments. Maize and melon planted in the early season did not seem to benefit much from organic fertilizer added probably because of low mineralization of nutrient from this source. (Table 5). Cowpea yield was highest where combination of inorganic and organic fertilizer was used but the least yield was also got from the control (no fertilizer). Highest yields of cowpea and cassava were recorded where inorganic + organic was applied because they are late season crops and benefited from organic fertilizer applied. Fuchs *et al.*, [6] reported that nutrients from mineral fertilizers enhance the establishment of crops while those from mineralization of organic manure promoted yield when both fertilizers were combined. Kang and Balasubramanian [13] also discovered that high and sustained crop yields could be obtained with judicious and balanced NPK fertilization combined with organic matter amendments. Murwira and Kirchman [17] observed that nutrient use efficiency might be increased through the combination of manure and mineral fertilizer. Crop yields were least in unfertilized plots because crops had to use the limited nutrients that the soil could supply without any external inputs.

The yields of crops were increased by application of inorganic and organic fertilizers in this experiment but the changes in soil nutrient status after cropping showed that there might be need to increase the level of organic material added to sustain the fertility of the soil. Organic fertilizer slightly increased the level of organic C, available P, exchangeable Ca and ECEC but total N and exchangeable K decreased after cropping. There is need for further research on complementary application of organic and inorganic fertilizers under intercropping system in order to improve both the physical and chemical soil properties.

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