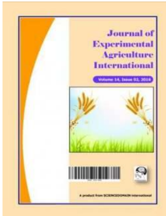

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Fertility Management for Cassava Production in the Centre Region of Cameroon

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Authors' contributions

This work was carried out in collaboration between both authors. Author CNT was responsible for the experimental set up (statistical analysis, literature searches and analyses of the study), field data collection and the writing of the draft manuscript. Author FAN designed the study, elaborated the research protocol, facilitated the field work and corrected the draft manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Cassava is a major food crop in Cameroon. It has the capacity to grow under poor soils or drought conditions. However, little is known about the impact of fertilizer application on cassava production on poor ferralitic soils of Cameroon. The aim of this study was to examine the effect of NPK (Nitrogen, Phosphorus and Potassium) fertilizer and poultry manure treatments on root yield of cassava (*Manihot esculenta* Crantz). The variety used (92/0326) was grown during the 2016/2017 cropping season in the Institute for Agricultural Research for Development (IRAD) experimental farm at Nkolbisson, Yaounde, characterized by a rhodic ferralsol with very low pH and nutrient availability. Four treatments were applied: No input control (T0), 20-10-10 NPK fertilizer use (T1), 12-11-18 NPK fertilizer use (T2), poultry manure application (T3) in completely randomized block design. The data obtained were subjected to analyses of variance (ANOVA) using the IBM SPSS

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Statistics 20 Software. Level of significance was determined at 5% probability level. Pearson's correlation test was performed at 0.1%, 1% and 5% level of probability. The results showed a significantly ($P < .001$) higher vegetative growth with T3, T2 and T1 treatments compared to the control. In addition, the root yields were significantly higher ($P < .001$) in the fertilizer applied plots than the control. Thus, T3 was 149% > control, T2 65% > control and T1 33% > control. The dry matter contents were similar in control, T1 and T3, while a 10% decrease was observed with T2. Since organic and inorganic fertilizer use enhanced cassava root yield, it appears paramount to apply a combination of both fertilizer sources to obtain a stable increase in cassava yield under very poor ferralitic soils.

Keywords: Dry matter; ferralsol; Manihot esculenta; organic and inorganic fertilizer; poultry manure; root yield.

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is one of the most important food crops in Cameroon. It is grown in almost all the ten Regions of Cameroon [1,2]. Cassava is reputed to be a soil-nutrient depleting crop [3]. Furthermore, soils in sub-Saharan African countries have a low level of inherent fertility [4]. Thus, a minimal amount of nutrient input is required for an acceptable cassava yield [5,6] although the crop is known to grow and produce on poor soils. Some authors advocate the correction of soil nutrient deficiencies through the use of some fertilizer formulations [7,8]. However, the majority of cassava farmers neither know of these formulations nor use any other nutrient enhancement technology for cassava production. In addition, the use of fertilizer formulations requires proper soil analysis that only adds to the costs of production of the farmers. A better approach could be to test the effect of available fertilizers on the local market in order to select the most appropriate for cassava cultivation. Several works have already been carried out on the fertilization of cassava in Africa [8-12]. However, there is a wide heterogeneity across countries in soil physical and chemical properties, crop history and farm management. Thus, the objective of this study was to evaluate the effect of available fertilizer types (20-10-10, 12-11-18 and poultry manure) on cassava growth and yield in the Centre Region of Cameroon.

2. METHODOLOGY

2.1 Experimental Site

The experiment was conducted between April 2016 and April 2017 at Nkolbisson (N3°51'57''-3°52', E11°27'31''-11°27'36"), in the Centre Region of Cameroon and belonging to the Humid Forest Agro-ecological Zone. An average rainfall of 1 700 mm was recorded during the experimental period. The average daily temperature was estimated at 23-24°C (Source: climatic data service IRAD, 2016). The area is characterized by a bimodal rainfall pattern, with four seasons: Long rainy season from September to November, long dry season from December to February, short rainy season from March to June and short dry season from July to August. The experimental field had a gentle slope covered with an old fallow and dominated by *Panicum maximum* and *Chromolaena odorata*. Soil analysis was carried out in the Soil Analysis Laboratory of the Institute of Agricultural Research for Development (IRAD) of Nkolbisson.

Composite samples of the top soil (0-15 cm depth) were collected from the experimental field with an auger before seed bed preparation following the transect method [13]. About 200 g of the samples were analyzed for soil physical and chemical properties in the laboratory. Soil samples were air-dried at room temperature and ground to pass through a 2 mm sieve. For carbon (C) and nitrogen (N) analysis, the soil was finely ground to pass through a 0.5 mm sieve. Soil pH was determined in a 1:2.5 (w/v) soil: water suspension. Organic C was determined by chromic acid digestion and spectrophotometric analysis [14]. Total N was determined from a wet acid digest and analyzed by colorimetric analysis [15]. P was extracted using Bray extractant and the resulting extract analyzed using the molybdate blue procedure [16]. Exchangeable cations (Ca, Mg, K and Na) were extracted using the ammonium acetate (NH_4OAC, pH: 7) and determined by flame atomic absorption spectrophotometry. Cation exchange capacity (CEC) was determined using ammonium acetate.

2.2 Plant Material

The plant material used in this study consisted of an improved cassava variety, namely 92/0326. It is renowned for its resistance to African cassava mosaic disease and bacterial blight and its tolerance to mealy bugs and bacterial blight. The average yield of the variety 92/0326 is between 30-45 $t.ha^{-1}$ of fresh roots with a dry matter content of approximately 35-38%.

2.3 Experimental Design

The experimental design was completely randomized block design in four replicates. The experiment spread over an area of 544 m^2 (of which 448 m^2 for the test and 96 m^2 of border) and the terrain was a gentle slope. Thus, four treatment replicates were randomly assign on slope and the other four below slope to capture the gradients of soil fertility and slope. The treatments were as follows:

- Control or without fertilizer (T0);
- 20-10-10 NPK fertilizer (T1);
- 12-11-18 NPK fertilizer (T2);
- Poultry manure (T3).

2.4 Sowing and Amendment

Cassava was planted at the rate of one cutting of 25-30 cm in length per hole following a 1 x 1 m pattern. The cuttings were planted in such a way that 2/3 of the cutting was below ground and 1/3 above ground level with a 45° inclination. The poultry manure was applied at 20 $tons.ha^{-1}$ [7,12,17] on experimental plots before the cuttings were planted. The mineral fertilizers [N:P:K] [20:10:10] and [N:P:K] [12:11:18] were applied at 400 $kg.ha^{-1}$ (40 g/plant) [8,18] on experimental plots two months after sowing. Manual weeding was done as required. Harvesting was done 12 months after planting.

2.5 Data Collection on Agronomic Parameters

The petiole length and the number of leaves were recorded once monthly, starting at three months up to six months after planting. The plant height and height to first branching was recorded once monthly, starting at three and seven months respectively up to twelve months after planting.

At harvest, the cassava yield ($t.ha^{-1}$) was obtained by evaluating the weight of the tuberous roots on a sampling plot of 10 m^2 repeated four times per treatment and the average root weight was expressed in yield per hectare.

The dry matter (DM) content was calculated according to the following formula:

$$DM (\%) = (DMW/FMW) * 100$$

Where FMW: Fresh Matter Weight; DMW: Dry Matter Weight.

2.6 Data Analysis

The data obtained were tested for normality by the Kolmogorov-Smirnov and Shapiro-Wilk tests and the homogeneity of variances by the Levene test. They were treated by analysis of variance (ANOVA) with the IBM SPSS Statistics 20 software using univariate general linear model. Comparison and classification of means was done using Student-Newman-Keuls test at the threshold of 5%. Non-compliant data to the ANOVA assumptions (normality and homogeneity of variance) were analyzed by the Kruskal-Wallis test and averages were compared by the Mann-Whitney U test at the threshold of 5%. Relationships between the parameters were highlighted by the Pearson correlation test.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Soil analysis

The results of analysis showed that the soil at the experimental site was acidic, low in organic carbon content, total nitrogen, and poor in exchangeable base (Table 1). The soil type was rhodic compact ferralsol with red color derived from basic rocks with an average organic matter content and available P. The soil was sandy clay. The calcium (1.3 $cmol.kg^{-1}$ of soil) content associated with very low magnesium (0.26 $cmol.kg^{-1}$ of soil) and potassium (0.12 $cmol.kg^{-1}$ of soil) contents indicated a very poor soil fertility with very low nutrient mobility.

3.1.2 Phenology and development

The number of leaves per plant and petiole length under different fertilizer applications showed exponential growth and significant differences ($P < .001$) between treatments (Table 2). Compared to the control, the number of leaves per plant was significantly higher at T3, followed by T2 and T1. The length of the petioles at T3 was significantly greater compared to T2, that of T2 was significantly greater compared to T1, and that of T1 was significantly greater than the control (Table 2).

A curve of the regression equations for number of leaves from 3 to 6 in increments of 0.1 is presented in Fig. 1.

The plant height and height to first branching under different fertilizer applications showed exponential growth and significant differences ($P < .001$) between treatments (Table 3). Plant height at T3 was significantly greater with respect to T2; T2 was significantly greater compared with T1, and T1 was significantly greater than the control. Compared to the control, height to first branching was significantly higher at T3, followed by T2 and T1 (Table 3).

3.1.3 Yield and dry matter content

Significant responses to fertilizers were observed for the root dry matter ($P = .01$) and yield ($P < 0.001$) (Table 4). The dry matter contents were similar in control, T1 and T3. However, less significant responses ($P = .01$) in dry matter content were observed on T2 treatment (with 10% decrease) compared with those grown without fertilization (Table 4). T3 recorded the highest yield (53.5 $t.ha^{-1}$) with a rate of increase of 148.8% compared to the control. It was followed by T2 (35.5 $t.ha^{-1}$) and T1 (28.5 $t.ha^{-1}$) with rate of increase of 65.1 and 32.6%, respectively.

Table 1. Soil characteristics of experimental site

Sand	Silt	Clay	pH KCl	pH H_2O	OM	OrgC	N	P	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC
%			-			$g.kg^{-1}$		$mg.kg^{-1}$			$cmol.kg^{-1}$		
39	15	46	4.41	5.75	46.98	27.25	1.71	7.41	1.30	0.26	0.12	0.10	6.07

The values were obtained from ten soil samples randomly taken from the experimental field

Table 2. Relationship between number of leaves per plant or petiole length (Y) and time (x in months) up to six months after sowing of cassava on control (without fertilizer), by 20-10-10 NPK fertilizer (T1), 12-11-18 NPK fertilizer (T2), and poultry manure (T3)

Parameters	Treatment	Time (months)	Regression equation	R^2
Number of leaves	Control	$3 \leq x \leq 6$	$y = 22.29e^{0.37x}$ (***)	0.99
	T1	$3 \leq x \leq 6$	$y = 27.24e^{0.38x}$ (***)	0.95
	T2	$3 \leq x \leq 6$	$y = 27.11e^{0.41x}$ (***)	0.93
	T3	$3 \leq x \leq 6$	$y = 35.85e^{0.50x}$ (***)	0.99
Petiole length (cm)	Control	$3 \leq x \leq 6$	$y = 18.69e^{0.04x}$ (***)	0.93
	T1	$3 \leq x \leq 6$	$y = 20.70e^{0.05x}$ (***)	0.98
	T2	$3 \leq x \leq 6$	$y = 22.33e^{0.05x}$ (***)	0.86
	T3	$3 \leq x \leq 6$	$y = 31.51e^{0.05x}$ (***)	0.97

$^*P < .05$, $^{**}P < .01$, $^{***}P < .001$. Values used are means from ten plants per experimental plot

Table 3. Relationship between plant height or height to first branching (Y) and time (x in months) up to twelve months after sowing of cassava, without fertilizers (control), with 20-10-10 NPK fertilizer (T1), 12-11-18 NPK fertilizer (T2), and poultry manure (T3)

Parameters	Treatment	Time (months)	Regression equation	R^2
Plant height (m)	Control	$3 \leq x \leq 12$	$y = 0.39x^{0.58}$(***)	0.98
	T1	$3 \leq x \leq 12$	$y = 0.52x^{0.60}$ (***)	0.99
	T2	$3 \leq x \leq 12$	$y = 0.58x^{0.59}$ (***)	0.99
	T3	$3 \leq x \leq 12$	$y = 0.97x^{0.56}$ (***)	0.97
Height to first branching (m)	Control	$7 \leq x \leq 12$	$y = 0.37x^{0.18}(***)$	0.91
	T1	$7 \leq x \leq 12$	$y = 0.41x^{0.23}$ (***)	0.95
	T2	$7 \leq x \leq 12$	$y = 0.40x^{0.33}$ (***)	0.95
	T3	$7 \leq x \leq 12$	$y = 1.11x^{0.14}$ (***)	0.95

$^*P < .05$, $^{**}P < .01$, $^{***}P < .001$. Values used are means from ten plants per experimental plot

Apart from the dry matter content which was not correlated with any other variable, the other variables studied were strongly correlated with each other (Table 5). Thus, tuber yield was positively and significantly correlated to plant height (r: 0.6***), height to first branching (r: 0.61***), number of leaves per plant (r: 0.4**) and length of petioles (r: 0.52***). Plant height was positively and significantly correlated to height to first branching (r: 0.91***), number of leaves per plant (r: 0.69***), petiole length (r: 0.85***) and yield (r: 0.6***).

3.2 Discussion

Fertilization use (poultry manure, NPK) significantly improved growth (number of leaves, petiole length, plant height, height to first branching), root dry matter content and cassava root yield. The no input control treatment recorded the lowest number of leaves, shortest plants (plant height and height to first branching) and least petiole length. This result is similar to those of several authors [7,19]. The positive response of growth characters to the applied nutrients is attributed to their role in cell multiplication and photosynthesis which gave rise to increase in size and length of leaves and stems [10]. The positive response of root yield to increase levels of N, P and K could be attributed to high starch synthesis and translocation activities stimulated by application of N, P and K [10]. Cassava is known to respond to organic and inorganic fertilizer applications. Several reports showed that the crop is responsive to fertilizer use [20,21].

N, P and K have been widely reported to be essential for plant root initiation; increase in tuber size and number [5]. The correlation between growth variables and yield could also explain this result.

The highest root yield was observed with poultry manure application (T3). This result could be attributed to favorable changes in the soil physical and chemical properties resulting to friable soil conditions, better soil aeration and root development. In addition, poultry manure is characterized by slow and constant release of

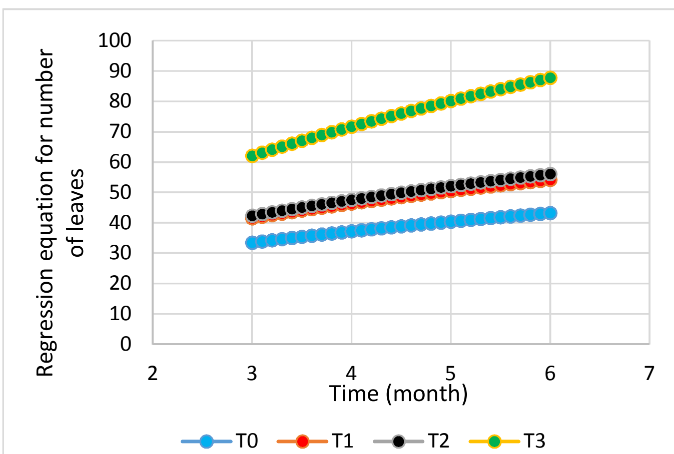

Fig. 1. Regression equations for number of leaves from 3 to 6 months

Table 4. Effects of fertilizer use on cassava yield on a ferralitic soil at IRAD experimental farm in Nkolbisson, Centre Region of Cameroon

Treatment	Yield ($t.ha^{-1}$)	RI Yield (%)	Dry matter (DM) (%)
Control	21.5 ± 11.7 a	0	36.1±0.2 b
T1	28.5 ± 8.5 ab	32.6	37.7±0.6 b
T2	35.5 ± 16.1 b	65.1	32.4±1.6 a
T3	53.5 ± 23.5 c	148.8	35.7±1.0 b
Fertilizers	***	-	**

**P < .05, **P < .01, ***P < .001. Values with the same small letter for each measured parameter are not significantly different at the .05 probability level. Mean yield ± Standard deviation of means of 10 repetitions. Mean Dry matter ± Standard deviation of mean of four repetitions. RI: Rate of increase*

Table 5. Pearson correlation matrix of cassava measured variables

	Yield	Dry matter	Height 12 MAP	HFB 12 MAP	Leaves number 6 MAP	Petiole lenght 6 MAP
Yield	1					
Dry matter	-0.173^{ns}	1				
Height	0.598***	-0.057^{ns}	1			
HFB	0.608***	-0.034^{ns}	0.908***	1		
Leaves number	0.351**	-0.037^{ns}	0.685***	0.685***	1	
Petiole lenght	0.515***	-0.057^{ns}	0.845***	0.858***	0.622***	1

*ns: not significant; *P ≤ .05, **P ≤ .01, ***P ≤ .001. HFB: height to first branching, MAP: Month after planting*

nutrients that is important for long duration crops such as cassava. This could explain why poultry manure recorded an increase in single root weight per stand [22] and high biomass production [12].

T2 (NPK: 12-11-18) was better compared to T1 (NPK: 20-10-10) in promoting growth and yield possibly because it contained more K and less N. Indeed, a high N application stimulates the production of excessive foliage [19] and poor root development by the plants. Furthermore, a high N fertilizer application results in a reduction in root yield [8]. Meanwhile K, in addition to its role in photosynthesis, promotes the circulation of the ascending sap in the xylem and the transfer of assimilates (sugars, amino acids) to roots and storage organs (grains, fruits, tubers). According to Adjanohoun [23], cassava plants consume more K than N and P. He noted that the amount of K extracted by cassava plants is more than twice that of N. The level of P was almost the same for the two chemical fertilizers used. Phosphorus promotes root development and increase the mass of roots, favoring nutrition and plant growth [24].

Dry matter accumulation was similar in control (36.1^{b}), 20-10-10 NPK fertilizer (37.7^{b}) and poultry manure (35.7^{b}) treatments. Earlier studies on organic manure and cassava productivity in Côte d'Ivoire reported dry matter contents ranging from 36.1-37.6% [9]. The scientists noted that the dry matter content increased with the application of fertilizers in certain varieties of cassava while in others little, or no change was observed.

It was observed that the control plots were more infested by weeds than the fertilized plots. This is probably because of a significant increase in vegetative growth in fertilized plants that led to the formation of a canopy, which certainly inhibited the growth of weeds. This result is in line with those of Fermont et al. [25] who observed that fertilizer use facilitated canopy closure in just three months after planting to suppress. Closure of crop canopy could also help to reduce runoff and hence soil erosion.

4. CONCLUSION

Fertilizer use enhanced soil nutrient status and led to an appreciable biomass accumulation and root yield of the improved cassava variety 92/0326. The highest root yield (53.5 t.ha^{-1}) was observed with poultry manure application and lowest (21.5 t.ha^{-1}) with the no input control. This portrays the importance of poultry manure and NPK fertilizer in enhancing cassava root yield in very poor ferralitic soils. Thus, a combined application of poultry manure and chemical fertilizer appears essential for a stable and sustainable cassava production in the Centre Region of Cameroon.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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