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Performance of Cassava (*Manihot esculenta* Crantz) Varieties under Different Soil Amendments

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Authors' contributions

This work was carried out in collaboration between both authors. Author KGS initiated and conducted the field experiment, managed and followed the field, collected and analyzed data, wrote and edited the draft manuscript. Author JSA was the main advisor who guided the field study proof read and re-organized the draft manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Studies were carried out at Offinso in the Ashanti Region of Ghana to assess root quality of cassava grown with application of poultry manure and NPK 15-15-15 and NPK 23-10-10 fertilizers. The experimental design was a 2 x 6 factorial, arranged in a Randomized Complete Block Design (RCBD) with three replications. The treatments consisted of two cassava varieties in combination with five inorganic and/or organic fertilizer formulations and a control with no fertilizer. The parameters measured were starch content, poundability, nitrogen, phosphorus and potassium contents of cassava roots. The data collected were subjected to analysis of variance using the Genstat Statistical package. The results of the study indicated that Bankyehemaa produced higher starch content (29.86%) than the Nkabom variety. Fertilizer application increased starch content with the combined application of poultry manure and NPK 23-10-10 treatment recording the highest

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treatment effect (30.40%). Both the organic and inorganic fertilizers applied increased starch content of cassava roots. Poundability was not also affected by both variety and fertilizer application. However, roots treated with NPK 15-15-15 only and poultry manure alone were very poundable (3.0). Variety significantly affected only nitrogen and phosphorus contents of cassava roots. Bankyehemaa had higher content (0.72%) of nitrogen than Nkabom, while Nkabom recorded higher content (1.05%) of phosphorus than Bankyehemaa. Generally, application of fertilizer significantly affected root contents of nitrogen, phosphorus and potassium. However, potassium and phosphorus contents were reduced by the organic fertilizer (poultry manure). The NPK 15-15-15 treatment produced higher potassium (9.37%) and phosphorus (1.36%) contents of roots than the other treatments. The highest nitrogen content of roots (0.78%) was observed in the combined application of poultry manure and NPK 23-10-10 treatment.

Keywords: Manihot esculenta; varieties; organic and inorganic fertilizers; starch content.

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a short-day and dicotyledonous perennial woody shrub which is grown principally for its edible starchy tuberous roots. According to [1], it is believed to have been introduced into Africa by the Portuguese from Latin America in the 16th century.

As of 2011, Ghana was the 7th highest producer of cassava in the world and third in Africa [2]. Work of Njoku et al. [3] indicated that Africa currently accounts for more than 50% of the world's annual output of 184 million tonnes of cassava with Nigeria being the leading producer in the world. Cassava is the most important food security crop in Sub-Saharan Africa with more than 200 million people depending on it as their main staple [4]. Studies of Oguntunde [5] depicted that cassava is a competitive crop, especially for the production of starch, animal feed and alcohol. Okogun et al. [6] found that in Africa, relatively few research activities on the use of fertilizer on cassava are carried out because very few farmers apply fertilizer to the crop. Luo et al. [7] found that organic fertilizer improves the physiological metabolism of cassava and also promotes the photosynthetic transfer to the root and increases number of root, yield and starch content in the roots of cassava. In a study to investigate yield performance of five cassava genotypes under different fertilizer rates, Parkes et al.[8] observed that the number of roots per plant was significantly influenced by fertilizer treatments. Tetteh and Frimpong [9] reported that cassava producers in Ghana do not apply fertilizer due to the belief that cassava does not require fertilizer; the cassava roots rot quickly when fertilizer is applied and the quality of cassava roots is reduced when fertilizer is applied.

The main objective of the study was to evaluate root quality of cassava following application of organic and inorganic fertilizers.

The specific objective of the study was, therefore, to determine the effect of poultry manure and NPK fertilizer on poundability, starch, nitrogen, phosphorus and potassium contents of roots of Bankyehemaa and Nkabom.

2. MATERIALS AND METHODS

2.1 Experimental Site

The research was conducted at Namong Senior High Technical School (6'45 N and 7'25 N, 1°65 W and 1°45 E with an elevation of 250 m- 300 m above sea level) in the Offinso Municipality of the Ashanti Region of Ghana from June, 2014 to May, 2016. The area falls within the moist semi-deciduous forest ecology and is characterized by a bimodal rainfall regime. The major season rains occur from mid-March to the end of July with a peak fall in June. The minor season rains commence in September and end in mid-November with a peak in October. The rainfall regimes are separated by a period of dry weather from December to March. The area also has a mean temperature range of 21°C to 30°C. A maximum temperature of 30°C is experienced between March and April, near monthly temperature is about 27°C. Annual rainfall ranges from 1500 to 1700 mm. Relative humidity is high during the major rainy season, reaching its peak of 90% between May and June. The soil belongs to the Kumasi series, which is locally classified as Ochrosols or Ferric Acrisol. The soil is moderately shallow, red, well drained, light clay and occurs at upper slopes. In this light, clay is frequently found and quartz merges with weathered rock with small mica flakes and light yellowish mottles [10].

Tables 1 and 2 show the chemical and physical properties of the soil at the experimental site, respectively.

Table 1. Soil chemical properties of study site

Chemical property	Level
pH	6.45
Organic carbon (%)	1.71
Organic matter (%)	2.95
Nitrogen (%)	0.19
Phosphorus (ppm)	6.78
Exchangeable cations (Cmol/kg)	
Potassium	0.17
Calcium	4.81
Magnesium	1.60
Sodium	0.09
EXC Acidity (Al + H)	0.10
CEC (Cmol/kg/Me/100g)	6.77

Table 2. Soil physical properties of study site

Soil separates (%)	% Composition
Sand	71.78
Silt	18.22
Clay	10.00
Texture	Sandy loam

2.2 Experimental Design and Treatments

The experimental design was a 2 x 6 factorial with treatments arranged in a Randomized Complete Block Design (RCBD) with three replications. There were thus twelve treatment combinations. The treatments comprised two cassava varieties in combination with five inorganic and/or organic fertilizer formulations and a control with no fertilizer. The cassava varieties were Bankyehemaa and Nkabom. The fertilizer-manure levels were as follows:

- Control (No fertilizer)
- NPK 15:15:15 at 600 kg/ha (90 kg N ha^{-1}; 90 kg P_2O_5 ha^{-1}; 90 kg K_2O ha^{-1})
- NPK 23:10:10 at 600 kg/ha (138 kg N ha^{-1}; 60 kg P_2O_5 ha^{-1}; 60 kg K_2O ha^{-1})
- Poultry Manure (PM) at 2 t/ha (1.2% N, 1.92% P, 0.58 K, 5.10% Ca, 5.10% Mg, 0.20% Na, 1.75 pH)
- ½ PM + ½ NPK 15:15:15 (½ PM + 45 kg N ha^{-1}; 45 kg P_2O_5 ha^{-1}; 45 kg K_2O ha^{-1})
- ½ PM + ½ NPK 23:10:10 (½ PM + 69 kg N ha^{-1}; 30 kg P_2O_5 ha^{-1}; 30 kg K_2O ha^{-1})

The planting materials consisted of mature stem cuttings (stakes) of about 20 cm in length, containing between 10 and 12 nodes. These were planted in an angled position at a spacing of 1 m x 1 m on a flat-tilled land.

2.3 Data Collected

The Reiman Balance was used to determine the starch content [11]. It works based on the specific gravity. Two kilograms of roots were taken and immersed in water and the weight taken using the balance. Starch was determined with the relation: Starch Content (%) = Dry Matter Content (%) – 4.61 [12].

Where,

Dry Matter Content = 158.3 x Specific Weight – 142 [13].

Cassava roots were taken from each treatment and boiled for approximately 45 minutes. These were ranked by experienced chop bar operators for the mealiness of the roots on a scale of 0 to 3 (0= non-poundable, 1= fairly poundable, 2 =poundable and 3 = very poundable). Nutrient composition of roots was determined through proximate analysis. Samples of tuberous roots were taken at harvest at 11 months after planting, oven dried (60°C) and ground with agate mortar and pestle, to pass through 0.5 mm pore size. N was determined by Kjeldahl method, P by molybdenum blue colorimetry and K by flame photometer.

2.4 Data Analysis

The data were subjected to analysis of variance using the Genstat Statistical package [14]. The Least Significant Difference (LSD) at 5% probability was used to compare treatment means.

3. RESULTS

3.1 Starch Content and Poundability

The difference between the two varieties for root starch content was significant ($P<0.05$). The mean starch content of the varieties was 29.86% for Bankyehemaa and 25.86% for Nkabom as shown in Table 3. Significant ($P<0.05$) differences occurred among the fertilizer treatments for starch content of roots. The control treatment produced the lowest starch content of 25.13%, which was significantly lower than all other treatment means, except that of NPK 15-15-15 only. The greatest starch content of 30.40% was measured in the combined application of poultry manure and NPK 23-10-10.

Table 3. Starch content and poundability of roots for two cassava varieties at harvest under fertilizer application in 2014/2015 growing season

Treatment	Starch content of roots (%)	Poundability of roots
Variety		
Bankyehemaa	29.86a	2.33a
Nkabom	25.86b	2.44a
Fertilizer		
Control	25.13e	2.33a
NPK 15-15-15	26.55cde	3.00a
NPK 23-10-10	29.29ab	2.33a
Poultry manure (PM)	27.89bcd	3.00a
NPK 15-15-15 + PM	27.90bc	2.33a
NPK 23-10-10 + PM	30.40a	2.33a
LSD (5%)		
Variety	1.30	NS
Fertilizer	2.26	NS
CV (%)	6.80	9.40

NS: Not Significant (P>0.05)

Poundability of roots ranged from poundable to very poundable (2.3- 3.0) with treatment application. Both varieties of cassava produced poundable roots (2.3-2.4). Roots treated with NPK 15-15-15 only and poultry manure alone were very poundable (3.0). The other fertilizer treatment effects on roots were poundable (2.3). The difference between varieties for poundability showed no significance (P>0.05). Similarly, the fertilizer treatments did not vary significantly (P>0.05) from one another in poundability (Table 3).

3.2 Nitrogen, Phosphorus and Potassium

Variety and fertilizer application significantly affected nitrogen content of roots (Table 4). Bankyehemaa plants had greater treatment effect than Nkabom plants. The combined application of NPK 23-10-10 and poultry manure was similar to the combined application of NPK 15-15-15 and poultry manure, and this was significantly higher than all other treatments. The control and NPK 23-10-10 treatments were similar. The NPK 15-15-15 treatment was similar to poultry manure treatment, and this was significantly lower than the other treatments.

Phosphorus content of roots varied significantly (P<0.05) between Bankyehemaa and Nkabom varieties (Table 4). Nkabom variety produced greater treatment effect than Bankyehemaa. Phosphorus content of roots was significantly (P<0.05) affected due to application of fertilizer. NPK 15-15-15 produced the greatest treatment effect, while poultry manure produced the lowest treatment effect. The treatment effects of the mineral fertilizers were similar, and these were significantly different from the other treatment effects. The treatment effects of the control and NPK 23-10-10 were similar. All other treatment effects were similar.

The potassium content of roots was not affected by variety, but was significantly affected by application of fertilizer (Table 4). Significant differences occurred among all fertilizer treatments with NPK 15-15-15 producing the greatest treatment effect and poultry manure recording the lowest treatment effect.

4. DISCUSSION

4.1 Starch Content and Poundability

There were significant differences in starch content of roots between the varieties and among the fertilizer-applied treatments (Table 3). Bankyehemaa variety produced greater starch content of 29.86% than that of Nkabom variety (25.86%) probably due to genetic differences between the varieties resulting in efficient usage of potassium for synthesis of starch in the former. In a similar study, Sarfo [15] reported starch content of 31.48% for Bankyehemaa. Fertilizer-applied treatments increased starch content and this is similar to that of [16]. The combined application of NPK 23-10-10 and poultry manure recorded the greatest treatment effect certainly because of its higher content of nitrogen relative to the other treatments, which could have enhanced the uptake of potassium. The manure component of the treatment could have also enhanced the availability and uptake of potassium. Potassium is required for formation of starch and its high

Table 4. Nitrogen, phosphorus and potassium contents of roots for two cassava varieties at harvest under fertilizer application in 2014/2015 growing season

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Variety			
Bankyehemaa	0.72a	0.86a	6.29a
Nkabom	0.70b	1.05b	6.22a
Fertilizer			
Control	0.71c	1.12bc	8.45b
NPK 15-15-15	0.64d	1.36a	9.37a
NPK 23-10-10	0.71c	1.19ab	8.05bc
Poultry manure (PM)	0.65d	0.61d	2.83f
NPK 15-15-15 + PM	0.77ab	0.70d	4.03e
NPK 23-10-10 + PM	0.78a	0.74d	4.79d
LSD (5%)			
Variety	0.01	0.13	NS
Fertilizer	0.02	0.23	0.46
CV (%)	2.10	20.40	6.20

NS: Not Significant (P<0.05); N: Nitrogen; P: Phosphorus; K: Potassium

uptake could have culminated in increased formation of starch. Studies of Parkes et al. [17] indicated that potassium is known to be involved in the formation of starch. The effect of K in increasing starch content of the roots was attributed to its role as a factor for a number of enzyme reactions in carbohydrate metabolism [18], particularly the polymerization of glucose to starch.

The difference between varieties for poundability showed no significance (P>0.05). Similarly, the fertilizer treatments did not vary significantly (P>0.05) from one another in poundability (Table 3).

4.2 Nitrogen, Phosphorus and Potassium

Variety and fertilizer application significantly affected nitrogen content of roots (Table 4). Bankyehemaa plants had greater treatment effect than Nkabom plants. This could be due to genetic differences between the varieties. The combined application of NPK 23-10-10 and poultry manure produced higher nitrogen content than the other treatments probably due to sufficient supply of nitrogen, phosphorus, potassium and micronutrients resulting in higher uptake of nutrients. For instance, according to Brady and Weil [19], potassium is useful for stimulating net photosynthetic ability of a leaf and increasing the translocation of photosynthates to the tuberous roots and also helps in the uptake of nitrates from the soil.

The effects of variety and application of fertilizer on phosphorus content of roots were significant (Table 4). Phosphorus content of Nkabom was higher than that of Bankyehemaa. The NPK 15-15-15 treatment produced higher phosphorus content of roots than the other treatments. This could be attributed to the higher concentration of phosphorus (15%) in that treatment relative to the others, which presumably could have promoted root growth and this may have increased uptake of nutrients such as phosphorus.

Ezeocha et al. [20] reported that application of poultry manure resulted in a significant increase in the phosphorus content of *D. bulbifera*. The result also supports findings of Falak et al. [21] who reported that NPK fertilizers had significant effect on nutrient composition of potatoes.

The potassium content of roots was not different for both varieties, but was significantly affected by application of fertilizer (Table 4). The NPK 15-15-15 treatment produced higher potassium content of roots than the other treatments. This could be ascribed to the higher concentration of potassium (15%) in that treatment relative to the others. This corroborates findings of Aziz et al. [22] who indicated that increase in K concentration due to added organic matter may be attributed to K concentration of organic matter and improved root growth. They further stated that better root growth is responsible for increased nutrient uptake in plants.

5. CONCLUSION

The cooking quality of cassava roots in terms of poundability was not affected when fertilizers were applied to the crop.

Both organic and inorganic fertilizers enhanced the starch content of cassava roots. However, the organic fertilizer reduced potassium and phosphorus contents of cassava roots.

Application of NPK 15-15-15 resulted in a higher residual effect of phosphorus and potassium in roots than the other nutrient-applied treatments and the control.

The combined application of NPK 23-10-10 and poultry manure produced a higher residual effect of nitrogen in roots than the other treatments.

COMPETING INTEREST

Authors have declared that no competing interests exist.

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