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# Cassava genotypes N P K nutrient uptake in leave and its growth and yield parameters regression under inorganic NPK (15-15-15) application rates in southern Mali, West Africa

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**ABSTRACT**

A sole inorganic fertilizer application study was done in southern Mali in Sikasso during the rainy season 2016-2017 to assess its effect on cassava growth and yields parameters. A randomized complete block design (RCBD) experiment with three replicates in two sites was used. The inorganic fertilizer used was the NPK (15-15-15) at 4 rates (0kg $^{ha-1}$, 100kg $^{ha-1}$, 200kg $^{ha-1}$ and 300kg $^{ha-1}$). Two cassava genotypes, *Bonima* (local) and *Sika* (from Ghana) were used in Finkolo and Loulouni. The fertilizer rates were applied in splits at equal quantity, two weeks after planting and the rest two months later. Analysis of soil nutrients before planting and plant leaves N, P and K content were performed. Data on numbers of branches, number of tubers per plant and fresh tuber yield were collected. The Least Significant Difference (LSD) at p=0.05 served to separate means. Our findings showed that *Sika* genotype and 300 kg $ha^{-1}$ of NPK are the best genotype and NPK (15-15-15) rates respectively in the two study sites. For the N, P and K content in the cassava leaves, the fertilizer effect was significant on P at 5 percent; while the N and K uptake were found to be affected by the site effect. Therefore site conditions should be considered when growing cassava. The Application of 300 kg $ha^{-1}$ of NPK increases cassava production allowing smallholder farmer's a progress for food security and higher profit. The results will inform and brief policies makers on cassava production in the country.



## Introduction

Cassava (*Manihot esculenta* Crantz), has gained the status of staple food crops in tropical countries principally due to the variability of foods derived from it for human and livestock use (Jean *et al.*, 2015). In addition this crop is a strategic crop based on its potential for famine mitigation in many tropical underdeveloped countries due to the fact that it provides the third source of calories in the tropics after rice and maize, especially in Sub-Saharan Africa (Frison and Felie, 1991; Ceballos *et al.*, 2004).

Cassava like any other production is mainly based on the availability of soil nutrients. These nutrients absorbed by plant root are stocked firstly in plant leaves before it distribution as assimilates to the other part of the plant to satisfy the crop nutritional need. Therefore the amount of these nutrients in crop leaves give an indication of it nutritional status. Howeler (2002) argued that the nutrient concentration of crops leaves is related to plant growth or yield. The scholar further argues that for cassava the best indicator tissue is the blade of the youngest fully expanded leaf.

The low production of cassava is related to the soil fertility. That was noticed by Ojeniyi *et al*. (2009), who pointed out that cassava production is limited by low soil fertility. That low soil fertility can be overcome by the use of inorganic fertilizers. Scholars Norman *et al.* (1995) and Obisegbor (2014) demonstrated that cassava is a heavy feeder crop, which explores a large volume of soil for nutrients, especially, nitrogen and potassium as well water. The crop, therefore, benefits from nitrogen and potassium fertilisation.

In the case of cassava production and fertilization requirement, some factors determine the realization of higher yield. For instance, soil fertility status of the farmland; cropping K levels in soil, the stimulated response of N fertilizers were highlighted as factors (Onwueme and Charles, 1994). In addition, the importance of phosphorus has been noted by Kim *et al*. (2013), in which the omission of the macronutrient from fertilizer mixtures result in poor yields and a reduction in starch content leading to the decrease in root weight.

Mali, a Sahelian country where cassava is grown in different agro-ecological zones got few data on the crop. The country shares the same issue of cassava low production due to low soil fertility status. However, it appeared that inorganic fertilization studies on cassava have been conducted in many parts of Africa, but paper published in Mali case remain few. Therefore this study aimed to fill this gap from the southern part of the country. An increase of cassava production for food security through a seeking for a proper NPK inorganic rates application and it response by two genotypes and finally the N P K uptake in cassava leaves constituted the objectives of this study.

## Material and methods

### *Experimental site*

The experiments were conducted in two sites located in the wider Sikasso administrative region of southern part of Mali based on their experiences in cassava production. The first site is located in Loulouni commune which belongs to Kadiolo district. The village is located at coordinates 10°54’0’’ North and 5°36’0’’ West. The commune, which includes a town and 28 villages, covers an area of 1,052 km$^2$. The elevation of Loulouni is at an altitude of 455 meter above sea level. The average annual rainfall is around 1,200 mm and extends from May/June to October/November while the dry season sets by November to May. The average annual temperature ranges between 21 to 32°C (PNUD, 2015). The dry season in the southern part of the country takes 6 month from November to April (Mali-Météo, 2007). The soils are classified as ultisols (FAO/UNESCO, 1990). Cotton, rice, maize, sorghum, groundnut, millet, sweet potato, potato, cassava and yam are the main crops grown in the zone.

The second site is located in Finkolo which is a rural commune of Sikasso district. Finkolo host a research station of the Institut d’Economie Rurale (IER) where the experiment was conducted. Finkolo *commune* covers 477 km$^2$ and includes 8 villages and is located in coordinates of 11° 5’59’’ North and 5°30’49’’ West. It is located at an altitude of 330 meter above sea level. The average annual rainfall is around 1,100 mm and its distribution is the same as Loulouni commune. The annual average temperature ranges between 24 and 32°C. The soils are also classified as ultisols (FAO/UNESCO, 1990). The major crops grown in the zone are yam, maize, sorghum, groundnut, millet, sweet potato, potato, fonio, rice, and cassava.

### *Experimental design*

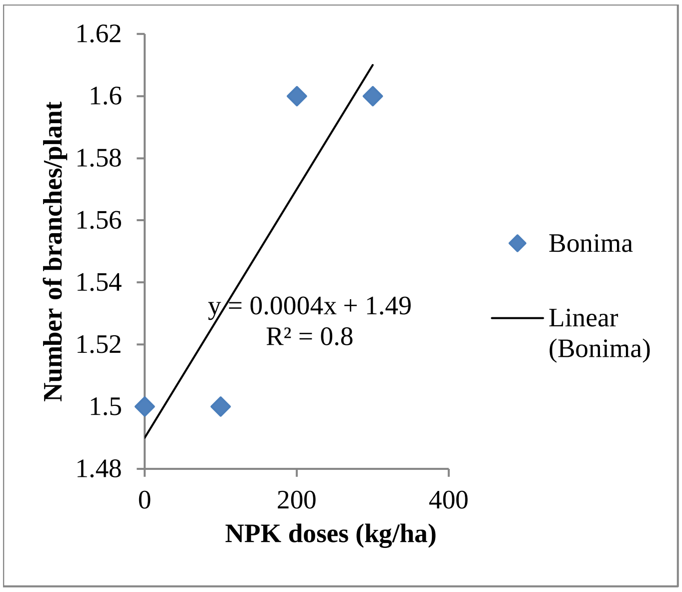


**Figure 1.** Regression of Bonima mean number of branches per plant and the four NPK doses in Loulouni site

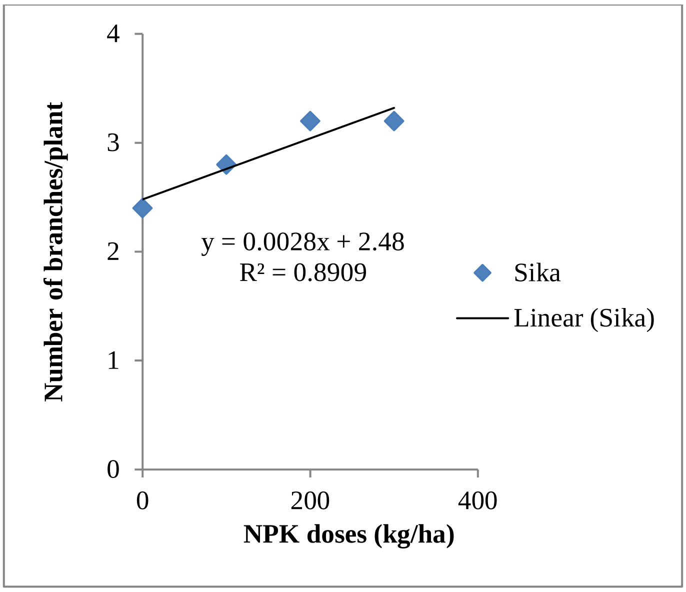


**Figure 2.** Regression of Sika mean number of branches per plant and the four NPK doses in Loulouni site

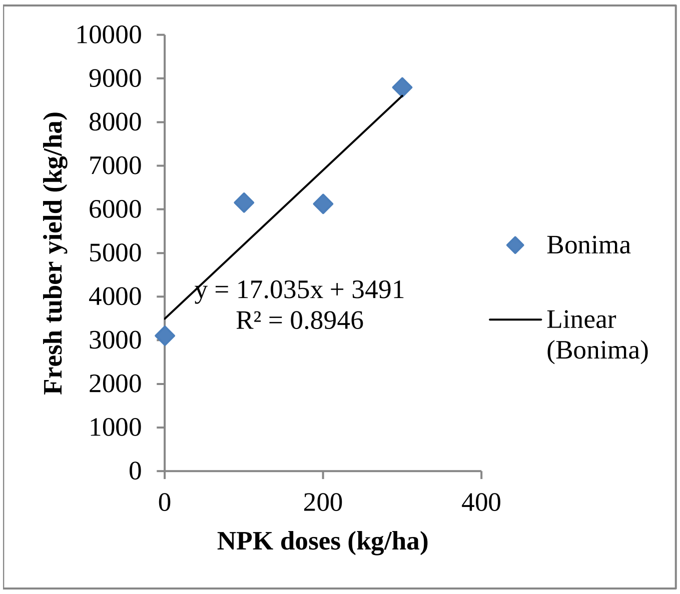


**Figure 3.** Regression of Bonima mean yield and the four NPK doses in Loulouni site

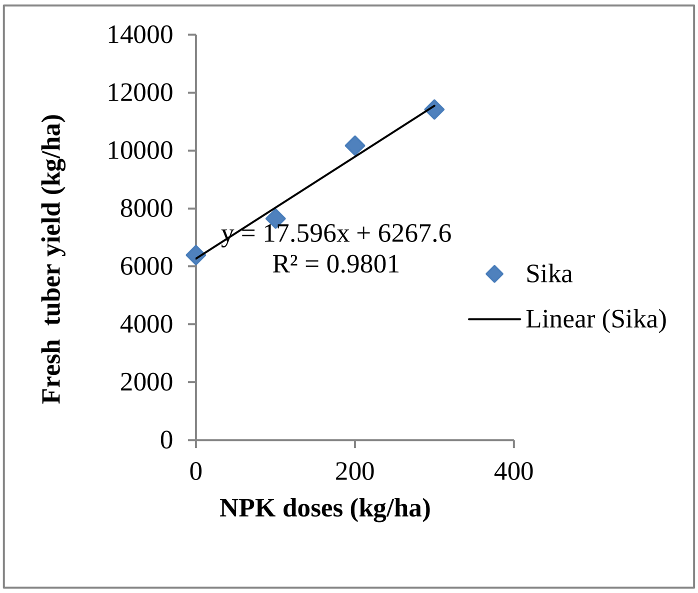


**Figure 4.** Regression of Sika mean yield and the four NPK doses in Loulouni site

The experiments were set up in a randomized complete block design (RCBD) with three replications; this result in 2 x 4 x 2 x 3 = 48 unit plots split equally between the two sites. Each unit plot had 5 lines of 4 m with 1 m between lines which is 160 m$^2$ by replication and a total of 480 m$^2$ for one experimental unit. They were one meter of alleys between subplots and two meters between replications.

The study involved three factors; two cassava genotypes, four NPK fertilizer rates and two experimental sites. The two factors combined will give 8 treatments per study site. The four NPK fertilizer rates were; 0 Kg NPK, 100 Kg NPK

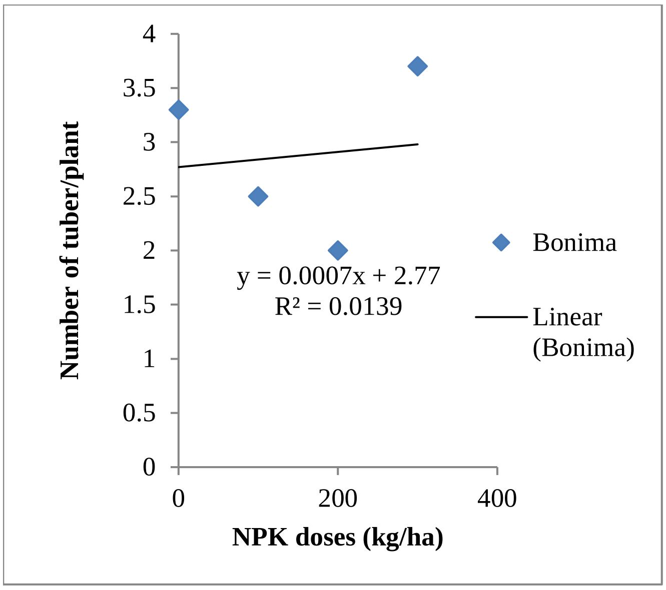


**Figure 5.** Regression of Bonima mean number of tuber/plant and the four NPK doses in Loulouni site

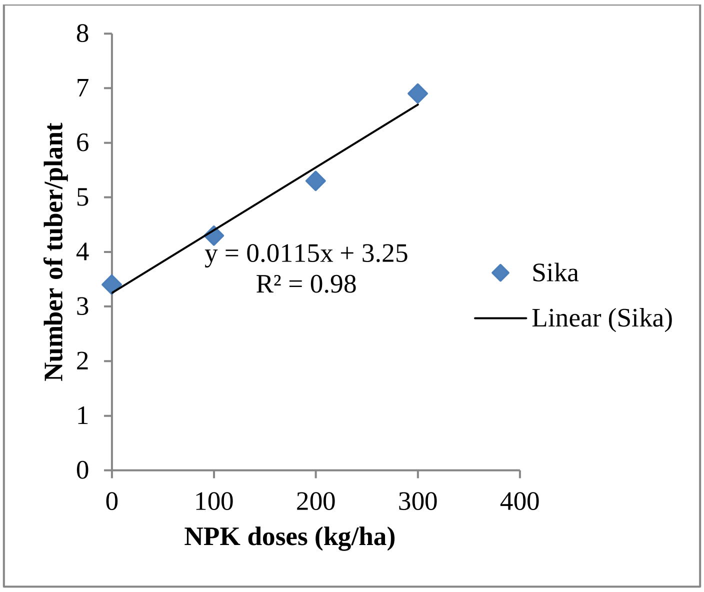


**Figure 6.** Regression of Sika mean number of tuber/plant and the four NPK doses in Loulouni site

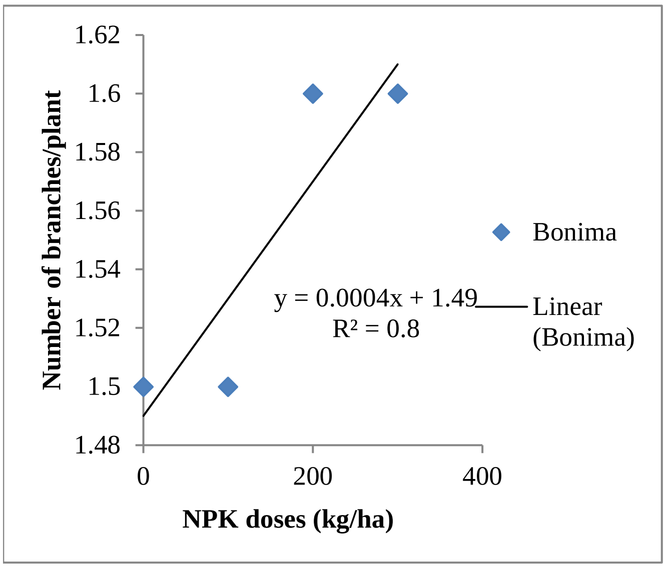


**Figure 7.** Regression of Bonima mean number of branches per plant and the four NPK doses in Finkolo site

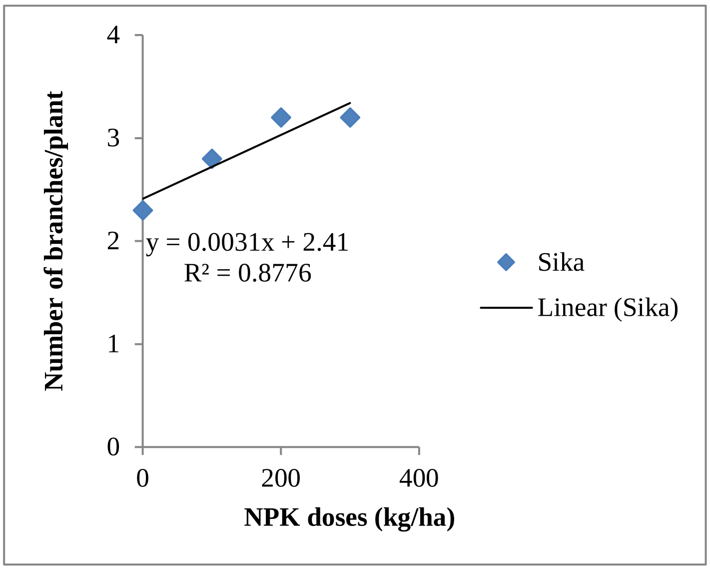


**Figure 8.** Regression of Sika mean number of branches per plant and the four NPK doses in Finkolo

(equivalent of 15kg N ha$^{-1}$, 15kg P ha$^{-1}$and 15kg K ha$^{-1}$), 200kg NPK (same as 30kg N ha$^{-1}$, 30kg P ha$^{-1}$and 30kg K ha$^{-1}$) and 300 Kg NPK (equal to 45 kg N ha$^{-1}$, 45kg P ha$^{-1}$, and 45kg K ha$^{-1}$).

***Planting material***

The two genotypes used were *Bonima* (a local genotype) and *Sika* (an improved drought and disease tolerant genotype from Ghana). The local genotype, *Bonima*, was obtained from the farmers whereas the improved genotype was supplied by Institut d'Economie Rurale (IER).

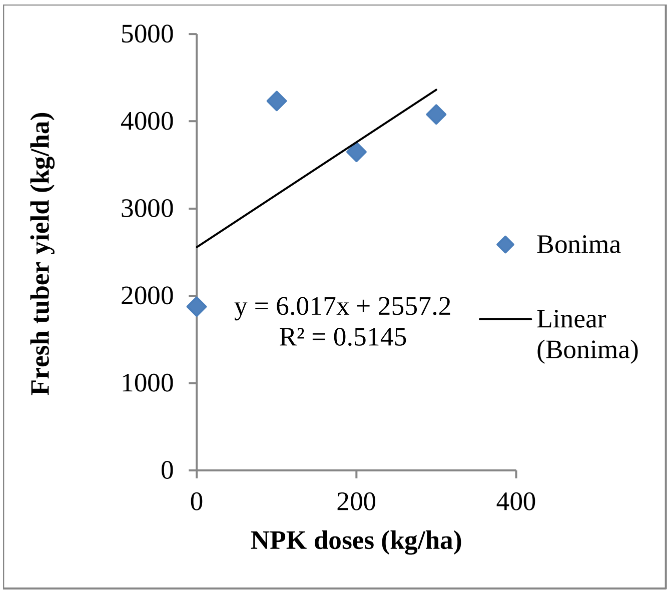


**Figure 9.** Regression of Bonima mean yield and the four NPK doses in Finkolo site

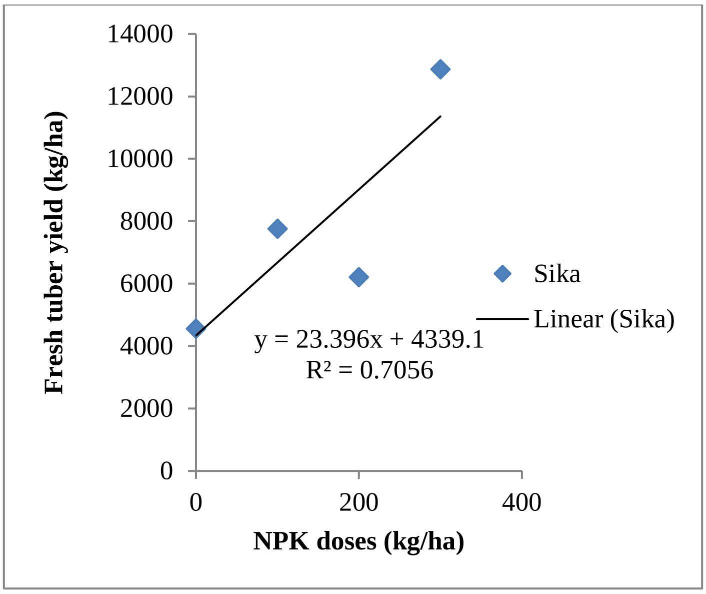


**Figure 10.** Regression of Sika mean yield and the four NPK doses in Finkolo site

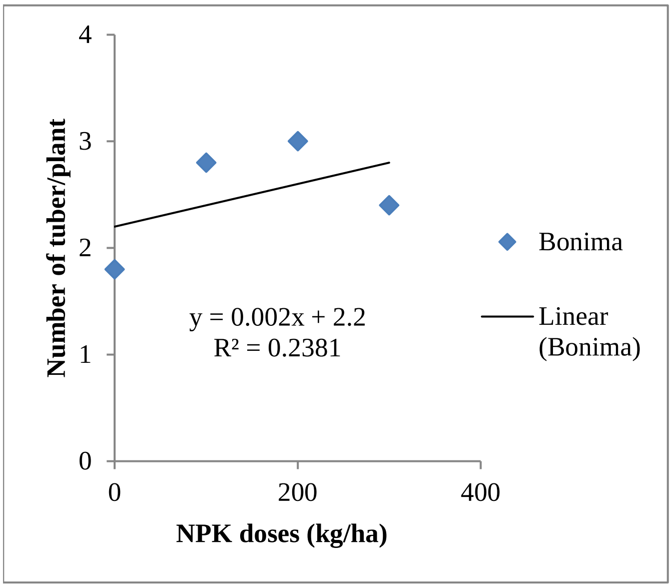


**Figure 11:** Regression of Bonima mean number of tuber/plant and the four NPK doses in Finkolo site

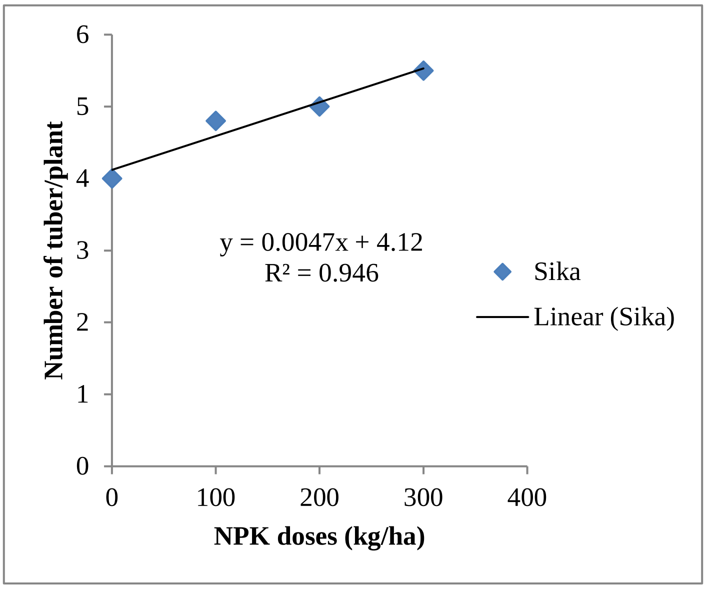


**Figure 12.** Regression of Sika mean number of tuber/plant and the four NPK doses in Finkolo site

***Experimental procedure and management***

The land was cleared of weeds and prepared for planting using hand implements. The seed beds were made into ridges of 4 meter long of one meter from each other. Cassava planting materials were cut into 20 cm long pieces and planted horizontally in the ridges by placing the two cutting in a hill. They were then planted at 1 m within a row and 1 m between rows. The NPK fertilizer (15-15-15) was applied by placing the NPK fertilizer treatment beside each cassava plant. This spot application technique is shown to increase the nutrient uptake efficiency by the plant (Bationo and Buerkert, 2001).

The cuttings were treated by fungicide before planting preventing cutting against fungal damage. Weeding was done two weeks after planting and repeated as needed. During the trial, termite attack was observed in Finkolo site and feradan (Cabofuran or $C_{12}H_{15}NO_3$) was used to control its damage in the trial. Fertilizer rates were applied in splits application, two weeks after planting and the rest two months later in spot application technique.

### *Data collection*

#### *Soil sampling and analysis*

Samples from topsoil (0-20) and subsoil (20- 40) from each experimental site (Loulouni and Finkolo) were collected for soil characterization. The soil analyses included physical and chemical analysis. In the physical analysis, soil texture was determined using the hydrometer method (Niang, 2004). Chemical analysis were focused on the pH in $H_2O$ (soil water ratio of 1: 2.5) using a pH meter, exchangeable bases $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, Cation Exchange Capacity (CEC) using ammonium acetate solution method, total nitrogen using the Kjeldahl method, available Phosphorus and soluble Potassium was extracted using Mehlich extractant and analysed using colorimetric spectrometry and flame spectrophotometry, respectively, and organic carbon was analysed using the Walkley-Black wet-oxidation method (Ayoola and Makinde, 2007).

#### *Plant tissue sampling and analyses*

Plant tissue samples were collected from fully expanded leaves at 4 months after planting. A total of 20 leaves from the net-plot of each treatment were collected (Howeler, 2014). The samples were cleaned using tap water in the laboratory then dried in an oven at 70℃ or below. After drying to constant weight, the samples were milled, sieved to pass through 1 mm sieve, and stored for N P K uptake analysis. The plant nutrient uptake were assessed for N, P and K by wet digestion method of plant material and analyzing the N by Kjeldahl method, P by the vanadium yellow method and K by flame photometer analyses (George *et al*., 2013).

#### *Cassava growth and yields parameters*

Plant growth and performance indicators chosen were the numbers of branches per plant, the number of tubers per plant, and the fresh tuber yield. The measurements were taken from 6 plants in the net-plot of each treatment at 9 months after planting. The selected cassava plants were tagged for the indicated measurements. The numbers of branches were counted on those attached directly to the main stem. The fresh tuber yields were expressed in number of tubers per plant and in tonnes per hectare of fresh tubers.

### *Data analysis*

The data collected on cassava from each site were analyzed combined. They were subjected to analysis of variance (ANOVA). When significant, the separation of means was done using the LSD test at P=0.05. Regression analysis was performed between fertilizer rates *vis a vis* number of tuber per plant, fresh tubers weight and number of branches per plant. All the statistical analysis was performed using SAS software version 9.3.

## Results and discussion

### *Soil characteristics*

Chemical and physical properties of the soils at the two sites are presented in Table 1. They both were classified as sandy loamy texture and low in organic carbon. The soils were medium acidity, as soil pH from 4.5 to 7 is considered medium for the nutritional requirement of cassava plant (Howeler, 2002). The exchange capacities (CEC) were low but exchangeable bases were of moderate levels with

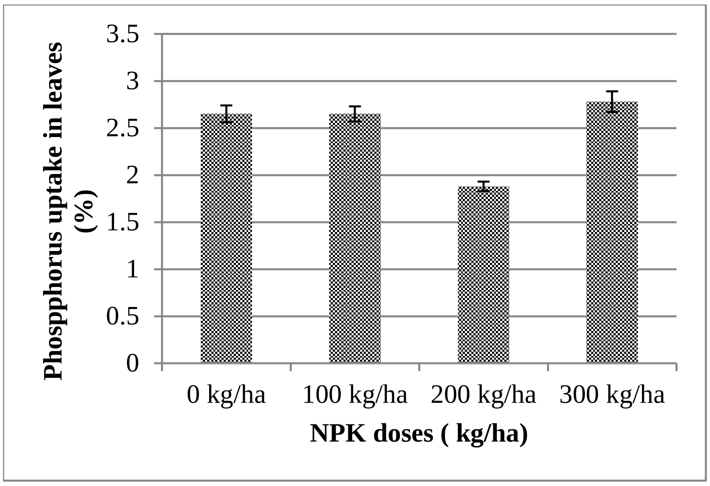


**Figure 13.** Effect of NPK fertilizer on the percent of phosphorus uptake in cassava leaves at 4 months after planting in the study area.

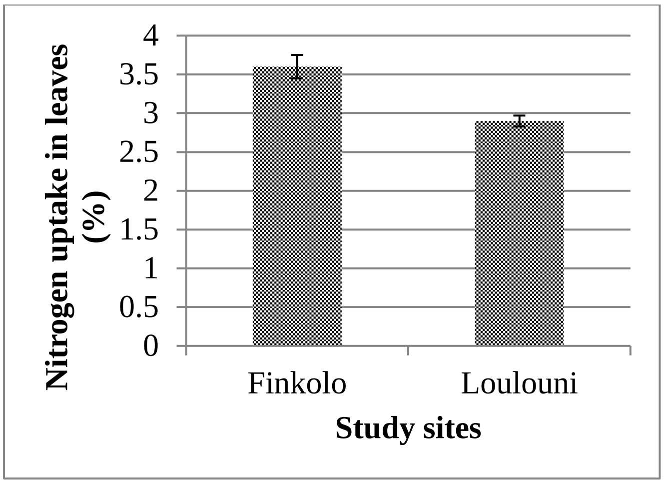


**Figure 14.** Effect of sites on the percent of nitrogen uptake in cassava leaves at 4 months after planting in the study area

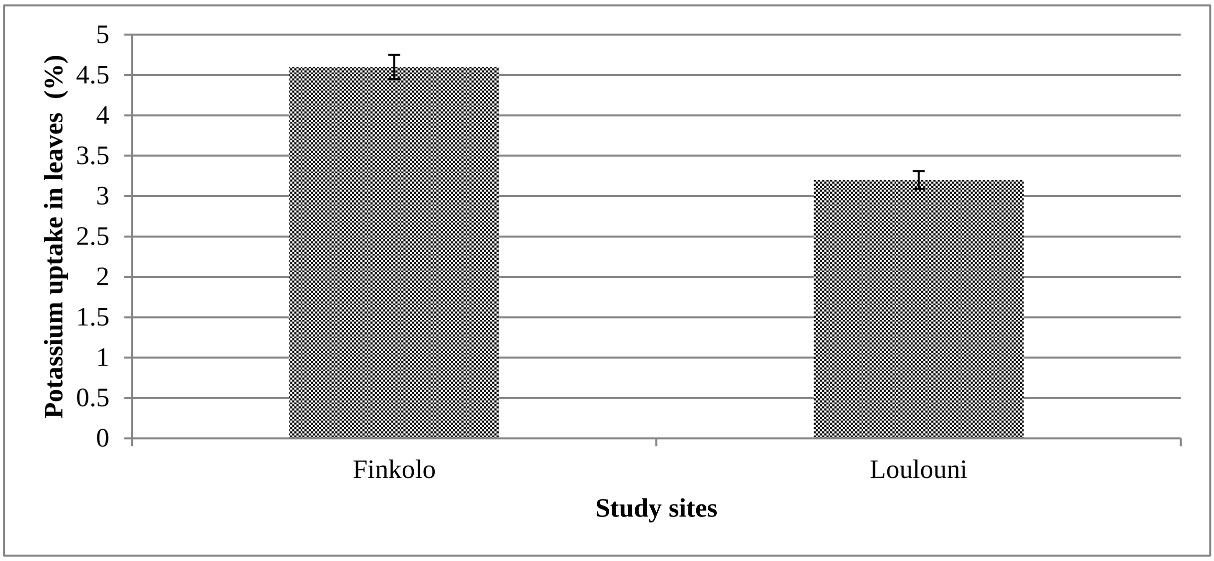


**Figure 15:** Effect of sites on the percent of potassium uptake in cassava leaves at 4 months after planting in the study area

low nitrogen level and very low of phosphorus content. The soil from the two study sites had low natural fertility status.

***Regression of inorganic NPK fertilizer rates on cassava growth parameters and yield***

Regression analysis between fertilizer rates versus fresh tubers yield, number of branches and tuber per plant are presented from Figure 1 to 12.

In Loulouni, the regression analysis showed that, cassava number of branches, number of tuber per plant as well fresh tuber yield of the two cassava genotypes increase as the NPK rates increase. The *Sika* genotype showed the highest coefficient of

**Table 1.** Chemical and physical properties of top and sub soil of experimental site

| | Loulouni site | | Finkolo site | |
|---|---|---|---|---|
| | Depth | | | |
| Parameters | 0-20 cm | 20-40 cm | 0-20 cm | 20-40 cm |
| pH( $H_2O$) | 5.78 | 5.79 | 5.80 | 5.81 |
| Organic carbon (% C) | 0.64 | 0.43 | 0.55 | 0.42 |
| Available phosphorus (ppm) | 1.28 | 0.83 | 7.41 | --- |
| Total Nitrogen %N | 0.03 | 0.01 | 0.02 | 0.01 |
| CEC meq/100g | 4.32 | 3.11 | 3.07 | 2.92 |
| Ca exchangeable (mg/Kg) | 334 | 194 | 194 | 176 |
| Mg exchangeable (mg/Kg) | 100.8 | 57.6 | 58.8 | 51.6 |
| K exchangeable (mg/Kg) | 117 | 58.5 | 35 | 35 |
| Na exchangeable (mg/Kg) | 1.32 | 1.32 | 1.32 | 1.32 |
| Sand % | 63 | 75 | 58 | 67 |
| Silt % | 33 | 23 | 40 | 31 |
| Clay % | 4 | 2 | 2 | 2 |
| Textural class | Sandy loam | Sandy loam | loam | Sandy loam |

regressions compare to *Bonima* with an r = 0.89, 0.98 and 0.98 for the number of branches, fresh tuber yield and number of tuber per plant respectively as presented in (Figure 2, 4 and 6). *Sika* genotype responded well to inorganic fertilizer than *Bonima*. The finding is similar to study by Onubuogu *et al.* (2014) in Nigeria which found that, cassava output was significantly related to the increases in fertilizer dose.

The regression analysis showed also in Finkolo that, cassava number of branches, number of tuber per plant and fresh tuber yield of the two cassava genotypes increase as the NPK rates increase; with *Sika* genotype providing the higher coefficient of regression like in Loulouni as presented in (Figure 8, 10 and 12).

### *NPK up take in cassava plant leaves*

In the study zones ANOVA showed that, the treatments site was significant at ($P<0.01$) on nitrogen uptake and significant at ($P<0.001$) on potassium uptake. The fertilizer level was found to be significant at ($P<0.001$) on the phosphorus uptake.

The effect of NPK fertilizer level on phosphorus content in cassava plant leaves is presented in (Figure 13). It was found that, the phosphorus uptake from 300 kg $ha^{-1}$ of NPK application which was 2.78% was found to be significantly different from the phosphorus content through the application of 0, 100 and 200 kg $ha^{-1}$ of NPK respectively. This implied that the application of the NPK increases the availability of phosphorus in the soil and had led to a significant uptake in the cassava plant leaves. Although its level was found in the toxic range more than 0.50% (Howeler and Cadavid, 1983). This finding is similar to study in which the leaf phosphorus content was found to be positively affected by the time of assessment and nitrogen dosages in the soil and was explained by the greater development of absorbing roots stimulated by the larger availability of N in the soil, which in return increased the explored crop area and, consequently higher P uptake (Nádia *et al.*, 2014).

The site effect on nitrogen content in cassava leaves is presented in (Figure 14). It was found that, in Finkolo site nitrogen uptake which was 3.6% was 24 % higher than it uptake in Loulouni where it was 2.9%. According to Howeler and Cadavid (1983), the N% in both study sites still very deficient as there are below 4.0%.This study is similar to finding in Puerto Rico in which the leaf nitrogen content of cassava plants grown at Corozal was significantly higher than that at Juana Díaz (Gustavo *et al.*, 2001).

In (Figure 15) is presented the effect of site on potassium uptake in Finkolo and Loulouni. It appeared that, the potassium uptake in Finkolo was found to be 44% higher than in Loulouni. The K level of 4.6% and 3.2% respectively in Finkolo and Loulouni were qualified as toxic since above of 2.40% (Howeler and Cadavid, 1983). The reason can be attributed to the fact that cassava plant in Finkolo got a favourable soil type and climatic conditions than in Loulouni for nutrient uptake in the leave at 4 MAP on the end of January month 2017. Irizarry *et al.* (1983) argued that, the fertilizer needs vary depending on factors such as soil type, cultivar, and climatic conditions prevalent during the growing stages.

Adequate supply of K is important for starch synthesis and translocation, and it also increases yield and improves tuber quality (Mehdi *et al.*, 2007).

## Conclusion

From this study, the regression analysis showed that the NPK (15-15-15) inorganic fertilizer increases both growth and yield parameters taken in consideration. The best levels of cassava output in growth and yield parameters were obtained through the application of 300 kg $ha^{-1}$ of NPK at both sites and should be therefore recommended. Our findings showed that, the phosphorus uptake from 300 kg $ha^{-1}$ of NPK application was found to be higher than it content obtained through the application of 0, 100 and 200 kg $ha^{-1}$ of NPK respectively. The level of N P and K uptake in the cassava 4 months leaves showed a deficient level for N and a toxic level for both P and K. About the choice of cassava genotype in our study sites condition we encourage *Sika* genotype which responded better to the application of NPK (15-15-15) than *Bonima*.

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