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Potassium Nutrition and Translocation in Cassava (*Manihot esculenta* Crantz) Intercropped with Soybean

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Authors' contributions

This work was carried out in collaboration between all authors. Author SIU designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors CCO and BUU managed the analyses of the study. Author SIU managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Experiment to investigate the effect of potassium nutrition and translocation in cassava (*Manihot esculenta* Crantz) intercropped with soybean (*Glycine max* (L) Merril) was conducted at University of Nigeria, Nsukka in a derived savannah location of South Eastern Nigeria. The Effect of application of potassium fertilizer on two varieties of cassava intercropped with six cultivars of soybean was studied. Cassava tuber yield was significantly ($P<0.05$) affected by their varieties, fertilizer rate and cropping system. An increase in the supply of K^+ by fertilization (N_0K_{50} and $N_{45}K_{50}$) increased K^+ accumulation in source leaves and caused increase in cassava tuber yield. The highest tuber yield of 42.0 t ha^{-1} was obtained with NR 8230 cassava variety intercropped with soybeans cultivars TGX 1894-3E with the application of N_0K_{50}, followed by NR 8230 intercropped with Samsoy-2 with $N_{45}K_{50}$ (40.5 t ha^{-1}).

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Keywords: Cassava; soybean; potassium; nutrition; intercrop; translocation.

1. INTRODUCTION

Potassium is an element essential to plant for the formation and transfer of carbohydrate in photosynthesis and also for protein synthesis. It is particularly important for the formation of fruits, leaves and stems and is needed to strengthen the plant's structure. Potassium promotes high crop yields, particularly in root and tuber crops. Potassium helps to direct free nutrients such as carbon, hydrogen and oxygen out of the atmosphere and into the plant. Various studies provide evidence that K^+ nutrition promotes the translocation of assimilates in plants. Without the activity of potassium, photosynthesis would be severely restricted and plant would struggle to make starches, sugars, proteins, vitamins, enzymes and cellulose. Net carbon exchange in plant increases as a result of increased K^+ fertilization [1]. The proportion of total potassium in soil expressed as K_20 held in soluble and exchangeable forms is usually very small in most of the tropical soils which is also faced with soil degradation and constant nutrient depletion.

Development of cropping system techniques to enhance good crop growth and yield resulted in intercropping legume with cassava in an intercropping system to alleviate the stress factors of poor soil- water and nutrient retention, improvement of soil microbial activity, providing more conducive environment and increased nitrogen supply through biological nitrogen fixation. In this study, soybean was considered suitable. This process may enhance the efficiency of plant nutrient uptake. Potassium aids in helping the plant through adverse climate in that, when potassium is out of balance with other soil minerals especially nitrogen, plant stress is very high [2]. When too much potassium is used, synergistic reaction occurs between calcium and magnesium, thereby changing the soil pH rapidly. At high pH, up to pH 6, potassium mobility slows down, and as soil reaches 7.0, mobility is severely hindered. Potassium reserve in soil is largely dependent on the type of soil mineral present in the soil. Soil potassium may be classified according to its availability to plants and falls into three categories: the inert reserve or slowly available K, the dynamic reserve and the readily available reserve [3]. The ratio of potassium exported through crop removal: exchangeable K indicates how long a farmer can afford to continue to extract K without adding potassium fertilizer. [4] reported that increasing applications of potassium fertilizer to barley crops grown on deficient sandy soils increased grain yield and decreased some foliar diseases. At the international Potash Institute (IPI), [5] categorised soils based on potassium reserve and production systems. They observed positive correlations with exchangeable and non-exchangeable K in all soil types indicating the dynamic equilibrium between the two soil- K^+ fractions. Increasing the K^+ available to the roots of cassava caused an increase to the delivery of K^+ to the leaves of the plant and possible increase in the cassava tuber yield [6]. [7] found that increasing K^+ supplies to the roots caused increased translocation of carbon in tomato fruits. Earlier studies [6] examined the responses of cassava varieties to N and K. [8], estimated the nitrogen need of cassava intercropped with soybean. This study was conducted to investigate the effect of potassium nutrition and translocation in cassava intercropped with soybean.

2. MATERIALS AND METHODS

The experiment was conducted at University of Nigeria, Nsukka farm which is located at latitude 06º 52''N and longitude 07º 24''E and at 447 m above the sea level, between August 2008 and July 2009. Experimental design was split plot in randomised complete block design, having two factors; fertilizer rates and cropping systems. Six varieties of soybean of three maturity classes (early, medium and late maturing) were intercropped with two varieties of cassava. Four fertilizer rates were randomised in the main plots, while twenty cropping systems comprising six sole soybean, two sole cassava and twelve cassava/soybean intercrop were randomised in the sub- plots.

Cassava varieties used were TMS 30572 and NR 8230. The six varieties of soybean used were TGX 1448-2E and Samsoy-2, (early maturing varieties), TGX 1894-3E and TGX 1805-31F, (medium maturing varieties), `TGX 1889-12F and TGX 1864-17F, (late maturing varieties). The four fertilizer rates were: N_0K_0, N_0K_{50}, $N_{45}K_0$ and $N_{45}K_{50}$ kg ha^{-1}, where N and K were nitrogen and potassium respectively, subscripts 0, 45 and 50 were levels of N and K kg ha^{-1} respectively. The nitrogen source was Urea and potassium source was muriate of potash. A uniform application of 30 kg ha^{-1} of P as single supper phosphate was applied to all plots.

Plot size was 4.0 m X 3.0 m., containing 4 ridges at 1.0 m spacing. Soybean was planted on both sides of the ridge at a plant distance of 10.0 cm while cassava was planted at a plant distance of 0.75 m. on the crest of the ridges. Both cassava cuttings (20 cm long) and soybean seeds were planted at the same time. Cassava plant population was 13,333.33 plants ha^{-1} while soybean was thinned down to plant population of 200,000 plants ha^{-1}. Planting was done in early August and weed was controlled manually. Cassava tuber yield, shoot dry matter and potassium content were determined at 12 months after planting. Uptake of K was determined as accumulation of K in cassava leaf and cassava tuber. Duplicate plant samples were dry-ashed and dissolved with 10 ml 6 M HCl. The K content of the digest was determined by flame photometer [9] according to the standard analytical method for potassium determination in plants.

2.1 Data Analysis

Data collected were analysed using procedures outlined by [10] for split plot in RCBD. Differences among treatment means were determined by the use of Fisher's least significant difference at 5% probability procedure outlined by [11]. Combined analysis of variance (ANOVA) was done using the general linear model procedure (GLM) to determine differences and effects between cropping system, soil amendment effect, crop yield and system efficiency.

Linear additive model of the system: $Xijk = u + \beta_1 + Tj + (BT)ij + \alpha K + (T\alpha)jk + \sum ijk$. Where: Xijk = Any observation; μ = Overall mean; β_1 = Block effect; Tj = Factor A; (BT)ij = Error (a); αK = Factor B; **(**$T\alpha$)jk = A x B Interaction; $\sum ijk$ = Error (b).

Key: N_0K_0 = 0kg N ha^{-1} and 0kg K ha^{-1}: N_0K_{50} = 0kg N ha^{-1} and 50kg K ha^{-1}:
$N_{45}K_0$ = 45kg N ha^{-1} and 0kg K ha^{-1} :$N_{45}K_{50}$ = 45kg N ha^{-1} and 50kg K ha^{-1}

3. RESULTS

Effect of potassium rate and cropping system on cassava tuber yield (t ha^{-1}) at 12 months after planting (MAP) was presented in Table 1. Application of N_0K_{50} fertilizer rate out-yielded all other fertilizer rates (30.7 t ha^{-1}). The tuber yield at $N_{45}K_0$ and $N_{45}K_{50}$ did not differ significantly (28.4 t ha^{-1} and 28.0 t ha^{-1} respectively). There were no significant yield differences between the two cassava cultivars as sole crop. However, at intercrop, NR 8230 intercropped with TGX 1894-3E produced significantly ($P < 0.05$) the highest tuber yield (30.8 t ha^{-1}) which was significantly higher than the sole crop (19.03 t ha^{-1}).

Table 1. Effects of fertilizer rate and cropping system on cassava tuber yield (t. ha^{-1}) at 12 MAP

Cropping systems (C)	Fertilizer rates (F)				Mean
	N_0K_0	**N_0K_{50}**	**$N_{45}K_0$**	**$N_{45}K_{50}$**	
NR 8230 Sole	4.2	22.1	24.2	25.6	19.0
TMS 30572 Sole	6.8	20.0	21.4	26.1	18.6
Early maturing variety					
NR 8230/TGX1448-2E	7.1	24.2	17.8	12.4	15.2
TMS30572/TGX1448-2E	13.1	23.5	36.5	35.6	27.2
NR 8230/Samsoy-2	10.5	33.8	30.1	40.5	28.5
TMS 30572/Samsoy-2	12.0	31.5	32.9	16.7	23.1
Medium maturing variety					
NR 8230/TGX 1894-3E	15.7	42.0	30.6	34.7	30.8
TMS30572/TGX1894-3E	11.5	38.9	32.6	22.0	26.3
NR 8230/TGX 1805-31F	9.7	38.2	30.4	32.8	27.8
TMS30572/TGX1805-31F	11.8	38.7	27.8	27.8	26.5
Late maturing variety					
NR8230/TGX1889-12F	14.6	35.5	32.6	32.6	28.6
TMS30572/TGX188912F	21.8	32.4	31.6	23.5	27.8
NR 8230/TGX 1864-17F	18.2	25.8	25.8	27.4	24.3
TMS30572/TGX186417F	19.6	23.6	23.6	25.3	23.0
Mean	12.5	30.7	28.6	27.4	

LSD0.05 for comparing two Fertilizer (F) means =0.51, $LSD_{0.05}$ for comparing two Cropping system (C) means = 0.58, LSD0.05 for comparing two (F x C) interaction means = 1.14

All intercrop cassava significantly ($P < 0.05$) out yielded sole cassava except NR 8230 intercropped with TGX 1448-2E (17.9 t ha^{-1}) which significantly yielded lower than both cassava sole crops (19.0 and 18.6 t ha^{-1} respectively). Generally, NR 8230 significantly out yielded TMS 30572 when intercropped with all varieties of soybean except with TGX 1448-2E, where the yield of TMS 30572 was higher than NR 8230.

The interaction of sole cassava x all fertilizer rates had generally lower tuber yields than when intercropped except at $N_{45}K_0$ and $N_{45}K_{50}$ x NR 8230 intercropped with TGX 1448-2E, N_{45} K_{50} x TMS 30572 intercropped with Samsoy-2 and TMS 30572 intercropped with TGX 1894-3E. The fertilizer rate of N_0K_{50} x NR 8230 intercropped with TGX 1894-3E gave significantly ($P < 0.05$) the highest cassava yield of 42.0 t ha^{-1} followed by the yield (40.5 t ha^{-1}) of the same cassava cultivar (NR 8230) x $N_{45}K_{50}$ intercropped with Samsoy-2. Medium maturing varieties, TGX 1894-3E and TGX 1805-31F, intercropped with the two cassava varieties gave a more close consistent tuber yield at N_0K_{50} (42.0, 38.9, 38.2 and 38.7 t ha^{-1}) which were significantly ($P < 0.05$) higher than all other soybean varieties x fertilizer rates both at sole and at intercrop. Cassava tuber yield was lowest at sole NR 8230 (4.2 t ha^{-1}).

Effects of potassium rate and cropping system on cassava leaf-K at 12 MAP were presented in Table 2. Cassava leaf-K differed significantly ($P < 0.05$) with potassium rates. Leaf-K at N_0K_{50} (2.71%) was significantly higher than other fertilizer rates, while leaf-K at N_0K_0 (1.89%) was the lowest.

Sole crops did not differ significantly among themselves. Intercrops of TGX 1448-2E with either varieties of cassava were similar (2.33%), while the intercrops of NR 8230 (2.45%) was significantly ($P < 0.05$) higher than TMS 30572 intercropped with Samsoy-2 (2.40%), (early maturing variety) TGX 1894-3E (2.55%) and TGX 1805-31F (2.30%), (medium maturing varieties) and at late maturing varieties, intercrops of TMS 30572 with both soybean varieties out yielded intercrops of NR 8230. At early maturing variety, highest leaf-K (2.45%) was obtained at NR 8230 intercropped with Samsoy-2 while at medium maturing varieties, NR 8230 intercropped with TGX 1894-3E gave the highest leaf-K (2.55%). At late maturing variety, the highest leaf-K was obtained with TMS 30572 intercropped with TGX 1864-17F (2.38%).

Cassava tuber-K at 12MAP, Table 3, showed that N_0K_{50} fertilizer rate produced the highest tuber –K (7.59%) followed by $N_{45}K_{50}$ (5.34%) while the lowest tuber-K was at N_0K_0 (2.96%). Intercropped cassava produced higher tuber-K (5.89%) than the sole crop (4.32%). The highest tuber-K (9.04%) was obtained at intercrop X N_0K_{50} which differed significantly with intercrop x $N_{45}K_{50}$ (6.31%) which was the next highest, while the lowest tuber-K (2.65%) was at sole crop x N_0K_0. Generally, the interaction of cropping system x fertilizer rates showed that intercropped cassava x all fertilizer rates had significantly higher tuber-K than sole crop x fertilizer rates.

4. DISCUSSION

The importance of inclusion of potassium was shown by the higher tuber yield of cassava at N_0K_{50} and $N_{45}K_{50}$ than at N_0K_0 and N_{45} K_0 fertilizer rates (Table 1). Increasing the K^+ nutrition in the system (N_0K_{50} and N_{45} K_{50} fertilizer rates) caused significant increase in the cassava tuber yield showing more effective translocation of nutrients in those systems with applied K^+. The potassium accumulation must have promoted increased tuber yield of cassava. [12] made similar observation and reported that increased K^+ nutrition on sugar beet plants promoted the translocation of products of photosynthesis, affect the metabolic conversion of sucrose in the sink tissues and resulted in net carbon increase and C/N ratio.

An increase in the supply of K^+ in the plant root zone by fertilization (N_0K_{50} and $N_{45}K_{50}$) increased K^+ accumulation in the leaves and tuber which caused increase in cassava tuber yield. The amount of K^+ in cassava leaf (Table 2) was between 1.8 % at N_0K_0 and 2.9 % at N_0K_{50}, while tuber yield was between 4.2 and 42.0 t ha^{-1}. At 12 MAP, the concentration of potassium in leaves is assumed to be at critical level where accumulation, concentration and translocation/distribution of assimilates must have been completed. The role of K^+ as a cofactor in synthetic metabolism has been well established [13]. The increased K^+ at the sink region may enhance the conversion of sucrose to synthesized metabolites and thus promote translocation into those sinks with enhanced K^+. Our result clearly showed that source potentials and sink capacities of the system at N_0K_{50} and N_{45} K_{50} have notable effect on the tuber yield capacities of cassava irrespective of the variety.

Table 2. Effects of fertilizer rate and cropping system on cassava leaf-K (%) at 12MAP

Cropping systems (C)	Fertilizer rates (F)				Mean
	N_0K_0	N_0K_{50}	$N_{45}K_0$	$N_{45}K_{50}$	
NR 8230 Sole	1.9	2.6	2.1	2.8	2.35
TMS 30572 Sole	1.9	2.7	2.1	2.6	2.33
Early maturing variety					
NR 8230/TGX1448-2E	1.8	2.8	2.2	2.5	2.33
TMS30572/TGX1448-2E	1.9	2.8	2.1	2.5	2.33
NR 8230/Samsoy-2	1.9	2.9	2.2	2.8	2.45
TMS 30572/Samsoy-2	2.0	2.7	2.1	2.8	2.40
Medium maturing variety					
NR 8230/TGX 1894-3E	2.1	3.2	2.1	2.8	2.55
TMS30572/TGX1894-3E	1.9	2.6	2.2	2.9	2.40
NR 8230/TGX 1805-31F	1.8	2.5	2.3	2.6	2.30
TMS30572/TGX1805-31F	1.8	2.5	2.2	2.4	2.23
Late maturing variety					
NR8230/TGX1889-12F	1.9	2.6	2.1	2.5	2.28
TMS30572/TGX188912F	1.8	2.9	2.1	2.6	2.33
NR 8230/TGX 1864-17F	1.8	2.6	2.1	2.8	2.33
TMS30572/TGX186417F	1.9	2.6	2.1	2.9	2.38
Mean	1.89	2.71	2.14	2.68	

LSD0.05 for comparing two Fertilizer (F) means = 0.01, LSD0.05 for comparing two Cropping system (C) means = 0.02, LSD0.05 for comparing two (F x C) interaction means = 0.04

Table 3. Effects of fertilizer rate and cropping system on cassava tuber – K (%) at 12MAP

Cropping system	N_0K_0	N0K50	N45K0	N45K50	Mean
Sole crop	2.65	4.37	6.14	4.13	4.32
Intercrop	3.27	6.31	9.04	4.92	5.89
Mean	2.96	5.34	7.59	4.53	

$LSD_{0.05}$ for comparing two fertilizer (F) means = 0.12, Two cropping system (C) means = 0.23, Two interaction (F x C) means = 0.33

The availability of biological nitrogen fixation and applied nitrogen at the intercrop system weakened the potential of N_{45} K_{50} system for higher root yield; rather there was observed higher vegetative cassava growth. There is likely hood that the larger root sink from N_0K_{50} due to potassium resulted in a higher rate of assimilation. The consistency, with which intercropped cassava at $N_0K_{50,}$ out yielded sole cassava, suggests some compensation of nutrient from biological nitrogen fixation (BNF). The level of nitrogen acquired through BNF seems to be sufficient for the growth and yield of cassava at N_0K_{50}. Additional applied nitrogen at $N_{45}K_{50}$ resulted to luxury nitrogen consumption, hence, higher vegetative growth. This observation explains why higher nitrogen fertilizer ($N_{45}K_{50}$) or biological nitrogen fixation (BNF) alone did not achieve the highest tuber yield of cassava. Also, it has been reported that the imbalance between exchangeable K and other soil minerals, notably calcium and magnesium, may result in total crop failure [14]. There was significant ($P < 0.05$) interaction between potassium rate and cropping system. Poor nutrient availability was evidenced by the lowest leaf-K at N_0K_0 x all the varieties. Our result showed that legume inclusion in the cropping system may have also contributed to better translocation of assimilates other than nitrogen contribution. However, not all the soybean cultivars used were very suitable. Our observation from the interaction of cropping system and fertilizer rates showed that medium maturing varieties TGX 1894-3E and TGX 1805-31F gave the best result for improving cassava yield at intercrop irrespective of cassava variety and fertilizer rate. Highest leaf-K obtained at N_0K_{50} and $N_{45}K_{50}$ fertilizer rates showed that without K fertilization (N_0K_0 and $N_{45}K_0$), residual soil potassium was very low. [15] reported that without adequate K fertilization in cassava, there was yield decline.

5. CONCLUSION

The highest cassava tuber yield (42.0 t ha^{-1}) obtained with the fertilizer rate of N_0K_{50} x NR

8230 intercropped with TGX 1894-3E was as a result of potassium nutrition and sufficient nitrogen supply from BNF. Highest tuber-K at N_0K_{50} confirmed effective translocation of K+ through the leaves with the highest leaf-K at N_0K_{50} and were significantly higher than other fertilizer rates, while tuber-K and leaf-K at N_0K_0 were the lowest. The superiority of inclusion of legumes for BNF and potassium fertilization in the cropping system was demonstrated by the highest performance of intercropped system and N_0K_{50} fertilizer rate.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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