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Effects of fertilizer and cassava-legume cropping systems on root yields in two agro-ecological zones of Ghana

Marcus Tobodawolo Jones[1*] and Roland Nuhu Issaka[2]

[1]Central Agricultural Research Institute (CARI), Suakoko District, Bong County, P .O. Box 3929, 1000 Monrovia 10, Liberia.
[2]Council for Scientific and Industrial Research - Soil Research Institute, Kwadaso – Kumasi, Ghana.

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Cassava is an important food crop in small-holder farming systems in Ghana. Due to the limited use of organic and inorganic inputs, soil fertility becomes a major problem in cassava production systems. A study was conducted at the Soil Research Institute, Kwadaso, in the Forest Agro-ecological zone and the Wenchi Agricultural Station in the Forest-Savannah Transitional zone. The fertilizer rates were 0:0:0, 15:15:15 and 30:30:30 N-P_2O_5-K_2O kg/ha. Cowpea, soybean, and groundnuts were the legumes and cassava was either sole cropped or intercropped with a legume. The objective was to determine the effect of fertilizer and cassava-legume cropping systems on root and grain yields in the two agro-ecological zones. Data on soil characteristics, biomass, grain, and root yields were collected. Growth and yield data were subjected to ANOVA and mean separated using LSD ($P < 0.05$). Fertilizer application did not influence cassava root yields at Kwadaso but different cropping systems significantly influenced root yield. Cassava-groundnut intercrop gave the highest root yield of 70.2 t/ha. At Wenchi, both cropping system and fertilizer did not affect root yield. This study shows that intercropping cassava with groundnut or cowpea is a good option in improving cassava production.

Key words: Agro-ecological zone, cassava-legume intercrop, fertilizer, root yield.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is an important staple food crop in Ghana with per capita consumption of about 153 kg/year (MoFA, 2012a). Cassava is cultivated as a monocrop or an intercrop with other food crops, either as the main or subsidiary crop. It covers about 21.68% of the total area of land grown to food crops in Ghana (MoFA, 2012b) and in 1995 to 1997 the area cropped to cassava increased from an average of 577,100 to 889,364 ha in 2011 (MoFA, 2009-2012). In the forest/savanna transitional agro-ecological zone of

*Corresponding author. E-mail: dawolo2005@yahoo.com.

Ghana where the bulk of cassava is produced, cassava has multiple uses. Despite being a major staple food crop, cassava serves as a source of income for most rural dwellers, where it is processed into either garri or cassava chips and exported to neighboring countries. In the forest/savanna transitional zone in Ghana in general and Wenchi in particular, cassava cropping is also used as a strategy to regenerate degraded soils (Adjei-Nsiah and Issaka, 2012).

Several grain legumes, including cowpea, groundnut, and soybean are selected as companion crops in many intercropping practices in the tropics due to their short duration and suitability in a cassava based intercrop (Polthanee, et al., 2001). Although introducing leguminous crops in intercropping systems is a unique strategy for soil nitrogen (N) improvement, Sanchez et al. (1997) argued that organic sources could not replenish soil fertility decline by themselves alone as they are gradually not available in sufficient quantities in most farms to fulfill the nutrient requirement of crops that will increase yield. Application of NPK fertilizer in cassava-legume based intercrop could be the best agronomic practice to improve soil fertility and increase crop yield. Ayoola and Adeniyan (2006) reported an increase in cassava root yield by 73 to 95% with the combined application of organic input and inorganic fertilizer in Nigeria.

In Ghana, cassava is found in a variety of crop production systems and performs well under various levels of management. Incorporating grain legumes into cassava based cropping system may be a desirable strategy to enchase protein intake and nutritional security for resource poor farmers whose staple is purely cassava. Cassava is a staple for more than 80 million people living in developing countries (Mtunguja, 2015) and has the potential to replace expensive imported raw materials such as starch and wheat flour for various African Industries. Ogola and Magongwa (2013) asserted that incorporating grain legumes into cassava based cropping system could augment the overall productivity of the system.

The objective of the study was to evaluate the effects of fertilizer and cassava-legume based intercropping systems on growth and yield components of cassava and crops.

MATERIALS AND METHODS

Study areas

The study was carried out concurrently in the forest savannah transitional zone of Wenchi (7° 44/ N, 2° 6/ W), in the Brong Ahafo region, and Kwadaso in the rain forest zone of Ashanti region (6°40′59″ N, 1°37′00″ W). The trials were established in April 2014 and cassava harvested in December 2015. The study sites were characterized by a bimodal rainfall pattern in which the major growing season is from April to July while the minor growing season is from September followed by a dry season from December to March.

Table 1. Initial physico-chemical properties of the soils.

Parameters	Values	
	Kwadaso	Wenchi
pH (2:1 H_2O/soil)	5.6	5.1
Organic carbon (gk g^{-1})	9.6	6.1
Total nitrogen (gk g^{-1})	1.2	0.1
Available phosphorus (mg kg^{-1})	20.9	10.5
Exchangeable K (Cmol kg^{-1})	0.2	0.1
Exchangeable Ca (Cmol kg^{-1})	3.4	2.0
Exchangeable Mg (Cmol kg^{-1})	1.0	1.0
Exchangeable Na (Cmol kg^{-1})	0.1	0.01
Exchangeable acidity (Cmol kg^{-1})	0.3	0.6
ECEC (Cmol kg^{-1})	5.0	3.9

Experimental design and layout

A factorial experiment comprising of two factors, fertilizer (3 levels) and cropping system (4 types), arranged in a Randomized Complete Block Design (RCBD) with three replications was used. The three fertilizer rates 0:0:0 (control); 15:15:15 and 30:30:30 kg N-P2O5-K2O/ha were applied to the cassava crop in the following cropping systems: pure stand cassava, cassava + cowpea, cassava + soybean, and cassava + groundnut. The plot size was 5.0 m x 10.0 m. Cassava was spaced at 100 x 100 cm in which there were five rows of cassava in each plot. Legume crops were spaced at 50 cm between rows with varying intra-row space of 20 cm, 15 cm, and 30 cm for cowpea, soybean, and groundnut, respectively. Details of the treatments are shown in Table 1. Fertilizer was applied around the cassava crop; prior to trial establishment, cassava was grown two years in succession at the Wenchi site while the site at Kwadaso was under fallow for one year.

A cassava variety (*Essambankye;* local name*)* and one variety each of the three legume crops were used in this study. The varieties of the grain legume used in the study included cowpea [*Vigna unguiculata (Asomdwee,* local name)*],* soybean, [*Glycine max* (*Nangba, local name)*] and groundnut [*Arachis hypogagea* (*Yenyawoso*-local name)]*.*

In both locations, land preparations were done manually with machetes and hoes. Debris were packed and removed from the site and the field was marked out for planting. Planting was done manually using a hand held hoe.

Parameter measured

Initial soil samples were collected from 0-20 cm depth and analyzed.

Agronomic performance of cassava in the intercrops

Ten plants were tagged for subsequent measurement of selected parameters of cassava. Six months after planting, litter trap was set in each plot measuring 100 by 100 cm^2 and raised slightly above ground to trap fallen leaf litter. The litter was collected every four weeks, oven dried at 70°C for 2 days for dry matter determination. Total biomass for cassava was determined at harvest; an area of 10 m^2 was harvested at 12 months after planting and separated into stem and leaves components. The roots were separated into marketable roots, non-marketable roots, and rotten roots as the case was for each plot.

Table 2. Number of cassava roots per plant as influenced by different rates of fertilizer and cropping systems.

Cropping systems	N-P_2O_5-K_2O (kg/ha)						Mean for CPS	
	0		15		30			
	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi
Pure stand	7.1	6.6	7.4	7.1	7.7	7.1	7.4	6.9
Cassava-Cowpea	6.9	5.2	9.5	7.5	8.8	8.2	8.4	6.9
Cassava-Soybean	7.7	6.9	8.5	7.1	8.6	8.6	8.3	7.5
Cassava-Groundnut	7.7	6.7	8.8	7.3	8.7	7.9	8.4	7.3
Mean for Fert.	7.4	6.3	8.5	7.2	8.4	8.0		
LSD (0.05) Fertilizer (Fert.):	NS	1.1						
LSD (0.05) Cropping systems (CPS):	NS	NS						
LSD (0.05) Fert x CPS:	NS	NS						

NS, Non significant; Fert, fertilizer; CPS, cropping systems, SED, Standard error of difference; LSD: Least significant difference.

Data analysis

Data on all parameters were subjected to analyses of variance (ANOVA) using Genstat Statistical Package. Least significant difference (LSD) was used for mean separation.

RESULTS AND DISCUSSION

Table 1 shows the physical and chemical properties of the soils and study sites before cropping. Generally, the soils were low in plant nutrients except available phosphorus (P) in the Kwadaso soil. At Kwadaso, the soil is relatively more fertile than that of Wenchi. Organic carbon (C), available P, exchangeable calcium and ECEC were higher than for Wenchi soil. Soil pH was acidic at Kwadaso but strongly acidic at Wenchi. The continuous cultivation at Wenchi may partly explain the observed trend since the plot at Kwadaso was under fallow.

Mean root number per plant

Mean number of roots per plant obtained in this study are presented in Table 2. Among all cropping systems at both Kwadaso and Wenchi, number of roots/plant was similar. Fertilizer gave similar results at Kwadaso however, at Wenchi 30:30:30 kg N-P_2O_5-K_2O/ha rate gave higher number of roots/plant than 0:0:0 kg N-P_2O_5-K_2O/ha.

The addition of fertilizer and cassava inter-planted with legumes did not influence mean number of roots per plant at Kwadaso probably due to the moderate initial soil nutrient level that may have favored the nutritional requirements for the cassava crop. According to Howeler (2002), average soil value of 1.5 cmol/kg for exchangeable potassium and 10 $mgkg^{-1}$ for available phosphorus are critical levels for cassava nutritional requirements. These findings are similar to that of Nyi (2014) who reported high number of cassava roots per plants in regions with low soil nutrient levels in DR Congo relative to regions with high soil nutrient levels, where fertilizer showed significant effect on number and yield of cassava. In Wenchi, nutrient supplied through NPK fertilizer may have been effective in supporting tuber initiation since initial soil nutrient level was below critical nutritional requirements for cassava especially exchangeable K. Additionally, this could be as a result of better synchronization of nutrient release and uptake by plants (Kapkiyai et al., 1998).

The findings support observations by Adjei-Nsiah, (2010) who reported significant increase in the number of cassava roots per plant at 30-60 N-P_2O_5-K_2O kg/ha. The initial soil conditions at both study sites showed that the soil condition at Kwadaso was ideal to support cassava production. This could probably be the major factor responsible for no influence of fertilizer on number of roots/plant at Kwadaso.

Mean root weight

Mean root weight (kg/root) ranged from 0.7 to 0.8 among fertilizer treatments at Kwadaso (Table 3). At Kwadaso, both cropping system and fertilizer gave similar mean root weight. Mean root weight was generally higher at Kwadaso (ranging from 0.7 to 0.8 kg/root) than Wenchi (ranging from 0.4 to 0.5 kg/root). The relatively better soil nutrient level at Kwadaso might have stimulated net photosynthetic activity and increases the translocation of photosynthates from the leaves to the storage roots (Howeler et al., 2001). However, the study did not show significant difference on mean root weight due to fertilizer application or cropping systems.

Root yield

The result of this study as shown in Table 4 did not show interaction effect of fertilizer and cropping systems on root yield across the two locations (Kwadaso and

Table 3. Mean root weight (kg) of cassava as influenced by different rates of fertilizer and cropping systems.

Cropping systems	N-P_2O_5-K_2O (kg/ha)						Mean for CPS	
	0		15		30			
	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi
Pure stand	0.7	0.3	0.7	0.5	0.7	0.5	0.7	0.4
Cassava-Cowpea	0.8	0.5	0.8	0.5	0.7	0.5	0.8	0.5
Cassava-Soybean	0.8	0.4	0.7	0.7	0.7	0.5	0.8	0.5
Cassava-Groundnut	0.8	0.6	0.8	0.5	1.0	0.4	0.9	0.5
Mean Fert.	0.8	0.4	0.7	0.5	0.8	0.5		
LSD (0.05) Fertilizer (Fert.):	NS	NS						
LSD (0.05) Cropping system (CPS):	NS	NS						
LSD (0.05) Fert x CPS:	NS	NS						

NS, Non significant; RT, root; CPS, cropping systems; SED, standard error of difference; LSD, least significant difference.

Table 4. Effect of fertilizer and cropping systems on root yield (t/ha) of cassava.

Cropping systems	N-P_2O_5-K_2O (kg/ha)						Mean for CPS	
	0		15		30			
	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi
Pure stand	51.3	24.8	45.1	32.2	56.7	34.9	51.0	30.7
Cassava-Cowpea	57.7	26.7	74.2	32.6	63.6	37.1	65.1	32.1
Cassava-Soybean	62.3	28.5	61.8	46.4	62.8	41.0	62.3	38.6
Cassava-Groundnut	60.5	35.6	68.5	35.0	81.5	32.4	70.2	34.3
Mean for Fert.	58.0	28.9	62.4	36.5	66.1	36.4		
LSD (0.05) Fertilizer (Fert.):	NS	NS						
LSD (0.05) Cropping systems (CPS):	12.2	NS						
LSD (0.05) Fert. x CPS:	NS	NS						

NS, Non significant; Fert, fertilizer; CPS, cropping systems; LSD, least significant difference.

Wenchi). At Kwadaso, root yield was significantly influenced by cropping systems. Cassava and legume combinations recorded significantly higher root yield relative to sole cassava. This might be due to the ability of the legume to provide adequate ground cover to retain soil moisture and improve the soil nitrogen level. Moreover, intercropping cassava with legume could also add organic matter input to the soil through the addition of legume biomass which improves physical, chemical, and biological properties of the soil and increase crop yield (Gerh et al., 2006). The root yield observed under cassava-groundnut (70.2 t/ha) was significantly higher than the pure stand but was not different from other cropping systems. Cassava-groundnut and cassava-cowpea (65.1 t/ha) were significantly higher than the pure stand. Pure stand and cassava-soybean did not differ significantly. The root yield observed under cassava-soybean and cassava-cowpea was not significantly different from each other. Pure stand recorded significantly lowest root yield in this study. The higher tuberous root yield observed under cassava-groundnut and cassava-cowpea intercrops could be due to the fact that groundnut and cowpea are short duration crops and matured just after the maximum canopy development of cassava and harvested earlier before an increase rate of tuber bulking process in the cassava crop. Additionally, cassava might have taken advantage of inter-specific competition for growth resources (space, water, and nutrient) between the two crops, for cassava was planted two weeks prior to introducing the legumes in their respective intercrops. Nyi (2014) also found that cassava yield can be increased considerably if cassava is planted early than the associated crop in an intercrop, creating strong inter-specific competition for growth resources in favour of the cassava crop at the time when the associated crop is still a weak competitor. The results suggest that cassava can be planted two weeks after groundnut and cowpea without affecting the tuberous root yield in the cassava-groundnut and cassava-cowpea intercrops.

At Wenchi, mean root yield obtained under fertilizer treatments ranged from 28.9 to 34.6 t/ha. Both fertilizer

Table 5. Effect of fertilizer and cropping systems on the total biomass yield (t/ha) of cassava.

Cropping systems	$N-P_2O_5-K_2O$ (kg/ha)						Mean for CPS	
	0		15		30			
	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi
Pure stand	87.5	45.3	91.1	53.1	96.0	54.5	91.5	50.9
Cassava-cowpea	93.7	43.8	129.7	53.4	116.5	56.9	113.3	51.4
Cassava-soybean	104.8	44.7	101.3	73.7	105.8	60.3	104.0	59.6
Cassava-groundnut	104.2	55.5	119.2	58.0	134.0	52.9	119.1	55.5
Mean for Fert.	97.5	47.3	110.3	59.6	113.1	56.1		
LSD (0.05) fertilizer (Fert.)	NS	NS						
LSD (0.05) cropping systems (CPS):	NS	NS						
LSD (0.05) Fert x CPS:	NS	NS						

NS, Non significant; Fert, fertilizer; CPS, cropping systems; LSD, least significant difference.

and cropping system did not influence root yield. However, the study did not indicate significant difference on root yield due to fertilizer or cropping systems. This might be associated to the low soil nutrient level as nutrients supplied through fertilizer and legumes inter-planted with cassava might have been adequate to improve the situation of low soil nutrient during the first growing season. Several authors (Dung et al., 2005; Osundare, 2007; Mbah et al., 2011) have shown that in the first growing season, crop grown in association with legumes in areas with low soil nutrient level, in most cases, the intercrops would make the most positive effect on yield and yield components in subsequent growing season.

Total biomass (cassava)

Table 5 contains the results obtained for total biomass yield at Kwadaso and Wenchi. Mean biomass yield ranged from 93.5 to 113.1 t/ha for fertilizer treatments and 91.5 to 119.1 t/ha for cropping systems at Kwadaso. However, both fertilizer and cropping system did not influence total cassava biomass. Similarly, fertilizer application and cropping systems did not significantly influence the result obtained for the total biomass yield at Wenchi. The nutrients supplied through fertilizer may have been readily available to the cassava crop. Such effect could contribute to decrease in photosynthetic area and thereby reduce biomass production (Laghari et al., 2010). Total biomass at Kwadaso almost doubled what was obtained at Wenchi. Better soil nutrient levels and higher rainfall at Kwadaso may be the main reasons. The values obtained for the total biomass of cassava at Kwadaso are not widely different from the figures reported by Esiape (2015) in a study to assess the influence of intercropping on growth and yield of cassava under similar agro-ecological at the Crop Research Institute, Fumesua, Kumasi, Ghana.

Marketable root

There was no significant effect observed on mean marketable root number per plant due to interaction effects between fertilizer levels and cropping systems in this study (Table 6). However, mean marketable roots per plant were significantly affected by cropping systems with cassava-ground and cassava-cowpea giving the highest of 6.8 and 6.2 roots per plant. There was no significant difference among cassava-groundnut, cassava-cowpea, and cassava-soybean intercrops. Pure stand recorded significantly lower mean marketable root number per plant (4.8 root/plant) than cassava-groundnut and cassava-cowpea but did not vary significantly from the mean obtained when cassava was intercropped with soybean. It could be assumed that the different legume intercrops might have contributed to maintaining a good soil moisture level, which is highly required for photosynthesis and tuber bulking. Moreover, due to the fact that the intercropped legume matured before competition developed between the two crop species, cassava had time to recover from the competitive effects of the legume (Fukai et al., 1990). Thus, cassava tuber initiation and bucking were not severely subjected to the intercrop competition, having harvested the legume earlier before the tuberization process commenced in cassava. Several authors including Polthanee et al. (2001) in a cassava-legume intercrop, Dung (2002) in a cassava-groundnut intercrop, Osundare (2007) in a cassava-legume intercrop, and Mebah et al. (2011) in a cassava okra intercrop reported a positive effect of intercropping on cassava marketable root yield as compared to pure stand. Conversely, neither fertilizer nor cropping systems seem to have contributed significantly to the mean marketable root number per plant recorded at Wenchi (Table 6). Mean number of marketable roots per plant observed among fertilizer treatments and cropping systems ranged from 2.6 to 3.3 roots per plant and 2.6 to 3.6 roots per plant. This might be associated to

Table 6. Number of marketable roots per plant as influenced by different rates of fertilizer and cropping systems.

Cropping systems	$N-P_2O_5-K_2O$ (kg/ha)						Mean for CPS	
	0		15		30			
	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi
Pure stand	4.9	2.1	4.2	2.7	5.4	2.9	4.8	2.6
Cassava-cowpea	5.5	2.5	7.1	3.0	6.1	3.4	6.2	2.9
Cassava-soybean	6.0	2.6	5.8	4.3	6.0	3.8	5.9	3.6
Cassava-groundnut	5.9	3.2	6.6	3.2	7.9	3.0	6.9	3.1
Mean for Fert.	5.6	2.6	5.9	3.3	6.3	3.3		
LSD (0.05) fertilizer (Fert.):	NS	NS						
LSD (0.05) cropping system (CPS):	1.3	NS						
LSD (0.05) Fert x CPS:	NS	NS						

NS, Non significant; Fert, fertilizer; CPS, cropping systems; SED, standard error of difference; LSD, least significant difference.

Table 7. Number of non-marketable roots per plant as influenced by different rates of fertilizer and cropping systems.

Cropping systems	$N-P_2O_5-K_2O$ (kg/ha)						Mean for CPS	
	0		15		30			
	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi
Pure stand	2.6	2.1	2.8	2.1	2.3	2.6	2.6	2.2
Cassava-Cowpea	2.2	1.9	2.2	2.9	2.3	3.3	2.3	2.7
Cassava-Soybean	2.1	2.4	2.4	2.6	2.4	2.9	2.3	2.6
Cassava-Groundnut	2.1	2.3	2.0	2.3	1.6	2.7	1.9	2.4
Mean for Fert.	2.2	2.2	2.4	2.5	2.1	2.7		
LSD (0.05) Fertilizer (Fert.):	NS	NS						
LSD(0.05) Croppingsystem (CPS):	NS	NS						
LSD (0.05) Fert. x CPS:	NS	NS						

NS, Non significant; Fert., fertilizer; CPS, cropping systems; LSD, least significant difference.

the differences in soil fertility status within the two study sites (Nyi, 2014) as competition for growth resources intensified between cassava and associated crop in a nutrient deficient soil especially when such occur during tuber bulking process, the resultant effects could reduce the yield and yield quality of cassava (Howeler, 2002). This could have probably accounted for the huge difference in the mean marketable roots per plant between the two sites.

Non-marketable

The number of non-marketable root per plant varied from 2.1 to 2.4 roots per plant among fertilizer treatments and ranged from 1.9 to 2.6 roots per plant under the cropping systems at Kwadaso (Table 7). At Wenchi, mean number of non-marketable roots ranged from 2.2 to 2.7 roots per plant among fertilizer treatments and cropping systems. The lowest mean value of non-marketable roots per plant was observed under pure stand while cassava-cowpea and cassava-soybean gave higher values relative to cassava-groundnut. However, the results of this study did not show single or interaction effects between fertilizer and cropping systems on the mean number of non-marketable roots per plant. Tuberous roots that were classified as non-marketable roots were either too small in size or were damaged by pests or diseases. It is noteworthy to say that even though treatments did not influence non-marketable roots per plant, these conditions were least observed in the intercrops at Kwadaso in which Nyi (2014) reported similar result. The author did not find significant effect between pure stand cassava and cassava-legume intercrops on non-marketable root yield.

Leaf litter

In addition to the fresh biomass, cassava litter was

Table 8. Effect of fertilizer and cropping systems on litter dry matter (g/m^{-2}) collected under 6-12 months old cassava

Cropping systems	N-P_2O_5-K_2O (kg/ha)						Mean for CPS	
	0		15		30			
	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi	Kwadaso	Wenchi
Pure stand	12.6	8.4	20.4	9.7	13.5	8.8	15.5	8.9
Cassava-Cowpea	14.1	14.0	13.1	15.7	15.9	17.3	14.4	15.7
Cassava-Soybean	15.1	14.4	15.2	16.1	16.3	15.9	15.5	15.6
Cassava-Groundnut	15.3	13.8	15.5	16.9	15.9	15.4	15.5	15.4
Mean for Fert.	14.3	12.7	16.1	14.6	15.4	14.3		
LSD (0.05) Fertilizer (Fert):	NS	NS						
LSD (0.05) Cropping system (CPS):	NS	NS						
LSD (0.05) Fert. x CPS:	NS	NS						

NS, Non significant; Fert, fertilizer; CPS, cropping systems; LSD, least significant difference.

estimated at full canopy (six months after planting) through to harvest (12 months after planting). The mean are presented in Table 8. At both sites, fertilizer and cropping system did not influence leaf litter.

Conclusion

Cassava legume intercropping system significantly contributed to tuberous root yield at Kwadaso. Fertilizer, however, did not affect root yield. Intercropping cassava with cowpea or groundnuts will also provide additional benefits from the grains produced by the legume. Biomass from the legumes may be beneficial to the follow-up crops after decomposition.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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