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Growth and yield performance of cassava under different plant population densities of two cowpea varieties in a cassava/cowpea intercrop

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Abstract Intercropping cassava with early maturing leguminous cover crop within the first three months can minimise the incidence of weeds in cassava farms and improve the yield of cassava. Studies were conducted in 2018 and 2019 cropping seasons to assess the effect of intercropping cassava with different populations of two cowpea varieties on the growth and yield of the component crops. The results indicated that yield and yield components of cassava were significantly higher in the intercropped cassava than the sole cassava in both cropping seasons. Significantly, the highest root yield was obtained when cassava was intercropped with cowpea at a cowpea population of 332,000 plants/ha in both cropping seasons, whereas the lowest root yield was recorded from intercropped cassava at cowpea population density of 110,000 plants/ha. Intercropped cowpea at a population density of 332,000 plants/ha had significantly the highest biomass yield in the 2018 and 2019 cropping seasons. The relative yield total, expressed as land equivalent ratio of the two crops was greater than 1.0 in all the intercrop plots. Intercropping enhanced the growth and storage root yield of cassava compared to sole cassava. The findings from this study suggest that cowpea can be successfully intercropped with cassava during the first three months of cassava growth without having any significant negative effect on cassava root yield for additional income.

Keywords: Cassava farms, Cowpea population density, Incidence of weeds, Intercropping, Yield total ratio

Introduction

Cassava (*Manihot esculenta* Crantz) is a major staple crop in Ghana and accounts for about 152.9 kg per capita consumption. Its carbohydrate-rich starchy storage roots are processed into gari, fufu powder, high quality cassava flour (used for bakery products) and *kokonte* (dry chips) to increase the shelf life (MoFA, 2009; Bayitse *et al.*, 2017). Cassava is cultivated in almost all parts

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of Ghana and its cultivation is further extending to other areas originally not noted for large scale cassava production. Though characterised by a monomodal rainfall pattern, the Northern region is gaining prominence for cassava cultivation and was ranked as the fifth leading cassava producer in Ghana (SRID-MoFA, 2014). This is due to the ability of the crop to give appreciable economic yields in areas where other crops would fail. For this reason, cassava is often cultivated on marginal soils with the perception that it depletes the soil (Asher *et al.*, 1980). By means of different physiological and morphological traits, the crop is able to mitigate the negative effect of harsh environmental conditions that prevail in this ecology (Adjebeng-Danquah *et al.*, 2020).

Though yield of 25-30 t/ha is possible in Ghana (SRID-MoFA, 2017), yields obtained in the Guinea savannah ecology have remained relatively low. This has been attributed to the inherently poor nature of the soils in the guinea savannah ecology. Earlier studies have reported that soils in northern Ghana are low in organic matter and most important plant nutrients particularly nitrogen and phosphorus (FAO, 2005). This situation has been aggravated by bad agronomic practices and bush burning leading to slow build up of organic matter. Removal of vegetative cover has resulted in the exposure of the soil to both water and wind erosion thereby accelerating the soil nutrient depletion process. Removal of crop residue after harvest and continuous cropping with inadequate replenishment of nutrients are some of the causes of soil nutrient depletion. Though Njoku and Muoneke (2008) suggested the use of inorganic fertilizer as a suitiable remedy, most farmers do not have access to adequate supply of inorganic fertilizer in a timely manner due to its high cost and challenges associated with the supply and distribution system. Additionallycontinuous application of inorganic fertilizer over the past decades has resulted in adverse residual effect leading to severesoil environmental degradation (Bationo *et al.*, 2006; Obiri-Nyarko, 2012). One way of addressing this problem is and making judicious use of the land is through intercropping with leguminous crops.

Intercropping-based farming system that involves the utilisation of legumes is considered as one of the efficient ways of improving soil fertility. Adjei-Nsiah *et al.* (2018) indicated that the integration of grain legumes in farming systems offers a potential pathway for sustainable intensification. This is because legumes have the ability to fix atmospheric nitrogen and their inclusion in the crop-mixtureis crucial in contributing to soil fertility improvement. Furthermore, grain legumes are used to improve soil fertility in smallholder farming systems in northern Ghana when their haulms are returned into the soil after harvest. One of the most common grain legumes often utilised in intercropping system is cowpea (*Vigna unguiculata* L. Walp.) which is compatible with most cereal-based cropping systems. Through an effective association with the suitable strain of rhizobium, the crop has the ability to fix up to 88 kg N per hectare per annum thereby supplying almost 90% of the crop total nitrogen requirement (Fatokun *et al*., 2002). This makes cowpea a very suitable crop in most cropping systems that are aimed at sustainable soil fertility management

Intercropping is one of the efficient ways to ensure maximum utilization of light and other growth resources, replenishing soil nutrients, prevention of soil erosion and better land use efficiency. Due to the slow initial growth of cassava in the first three months prior to canopy closure, farmers often spend several days or weeks controlling weeds in cassava farms. Phenological and physiological studies have shown that assimilates' partition in cassava during the first three months is directed towards the above ground plant parts till a maximum leaf area index is obtained (Alves, 2002; El-Sharkawy, 2004). Intercropping cassava with an early maturing crops will minimse the incidence of weeds in cassava farms, reduce the labour cost for weed control and also ensure judicious utilisation of the land. Since the success of any intercropping system depends on the choice of compactible crops, crop varieties and appropriate plant population for maximum yield, there is the need to consider these factors during the selection of the intercrops. The performance of cassava in intercropping systems with with cereals or legumes depends on the population of the intercrop partners. Thereby necessitating the need to determine the optimum population density for cassava based intercropping systems (Ikeorgu and Odurukwe, 1990). Isenmilla *et al.* (1981) also suggested that the choice of cultivar for intercropping should be based on knowledge of the growth habits and effects of environmental stress on the sole crops.

Higher biomass production of cowpea in cassava/cowpea intercropping systems may provide adequate ground cover for moisture conservation and contribute to yield increase of cassava. Furthermore, cassava may perform at its maximum capacity when the appropriate plant population density of cowpea is used in the intercropping system and adequate plant residue is obtained from the cowpea. However, currently there is little information on the performance of cassava when intercropped with cowpea and the appropriate cowpea population that is used in a cassava-cowpea intercrop to ensure optimum performance in the guinea savannah ecology. The objectives were to assess the effect of intercropping on the growth, yield and yield components of cassava and cowpea in a cassava/cowpea intercroping system using two varieties of cowpea (Padi-tuya and Kirkhouse Benga) in the guinea savanna zone of Ghana, and secondly to determine the optimum population of cowpea for the highest yield of cassava in a cassava-cowpea intercropping system.

Materials and methods

Description of the study area

The experiment was conducted for two cropping seasons in 2018 and 2019 at the CSIR-Savanna Agricultural Research Institute located at Nyankpala (9° 25′ N, 1° 58′ W, 183 m above sea level) in the Guinea Savannah agro-ecological zone of Ghana. The Guinea Savannah zone covers over 40% of the entire land area of Ghana and is characterised by high temperatures and low humidity for most parts of the year (EPA, 2003). The climate is a warm, semi-arid with mono-modal annual rainfall of 1200 mm between May/June and October. The area also experiences a long windy dry season (harmattan) annualy from November to April. Intermittent dry spells, often lasting up to two weeks also occur during the rainy season (Alua *et al.,* 2018). The land has a gentle slope of about 2 %. The soil is well-drained Voltaian sandstone, locally known as the Tingoli series and classified as ferric luvisol (FAO-UNESCO 1977).

Treatments, experimental design and planting materials

The experiment was laid out in randomized complete block design (RCBD) with three replications in both years. Treatment combinations consisted of three factors; three levels of cowpea population density (111,000 plants/ha, 166,000 plants/ha and 332,000 plants/ha), two cowpea varieties and two cropping systems (Sole and intercropping). The plant population density of the cassava was maintained at 10,000 plants/ha. An elite cassava genotype, 96/1613 was used. The cassava genotype 96/1613 is a branching type and matures within 12 months after planting. Two erect cowpea varieties; Kirkhouse Benga and Padi-tuya which mature within 62-65 and 70-75 days after planting respectively were used for the study.

Land preparation, planting and fertilizer application

The experimental field was ploughed and harrowed, after which ridges were made. A plot size measuring 4 m x 5 m was adopted for each treatment. Cassava planting material preparation and planting were done according to Adjebeng-Danquah *et al.* (2016). A spacing of 1 m x 1 m was adopted for planting the cassava. Each plot consisted of four rows with five cassava plants in a row. The cassava was intercropped with the cowpea varieties at one month after sprouting. The cowpea plants were spaced at 60cm between rows with varying intra-row spacings of 30 cm, 20 cm and 10 cm. The intercropped cowpea was planted at the side of the ridges giving eight rows of cowpea in a plot. No fertilizer was applied to the trials, but weeds were controlled using hand hoe when necessary. Reshaping of ridges was done to prevent exposure of the roots of the cassava. Cowpea plants were protected against insect pests using a non-systemic contact insecticide (Lagano 2.5 EC) containing 25 g of Lambda cyhalothrin per litre at a rate of 600mls/ha at 35, 45, 55 and 65 days after sowing.

Data collection and analysis

Soil samples were taken from each plot, bulked and mixed thoroughly to obtain a composite sample. A subsample of 200 g was taken and analysed for soil texture, pH in water using soil to water ratio of 1:2.5 (Page *et al.*, 1982). Total nitrogen of soil from the experimental plot was determined by Kjeldahl distillation and titration method (Bremner and Keeney, 1965). Available phosphorus was measured using Bray and Kurtz method (Bray and Kurtz, 1945). Exchangeable potassium was determined using flame photometry PFP7 after extraction with ammonia acetate. Organic carbon was determined by the wet digestion method (Nelson and Sommers, 1982) before planting was done.

Cowpea: At harvest, plant height was measured using a meter rule from the base of the plant to the tip of the main stem for each of the five randomly selected tagged plants and average calculated. Number of nodules per plant was obtained at full flowering. Number of pods per plant was determined by counting pods of five randomly selected plants at harvest. Number of seeds per pod was counted from five randomly selected pods at harvest. The grain yield obtained from the two inner rows was dried to a moisture content of 10 %. These were weighed and each weight used to estimate the yield per hectare. After harvesting the pods, the rest of the plant was also uprooted, dried and weighed to obtain the biomass yield.

Cassava: Plant height and canopy diameter of five randomly selected plants were measured with the aid of a meter rule at three months, six months and 12 months after planting. The plant height was measured from the base of the plant to terminal bud while canopy diameter was determined by placing the meter rule across the diameter of the canopy (from one end to the other end). The yield and yield components were taken from five plants sampled randomly from two middle ridges of each plot. Number of roots per plant was determined by counting roots from five plants and their average calculated. Root length (cm) was measured from one tip to the other with a measuring tape. Root width (cm) was also determined by measuring the widest portion of the same roots using vernier callipers. Roots from two middle rows for each plot were weighed and converted to t/ha for each plot to determine root yield. Storage root dry matter content was estimated by first chopping five selected roots from each plot into pieces (about 1 cm thick) and mixed thoroughly. Afterwards, 100 g of each sample was taken and dried at 80 ^{0}C for 48 h and weighed. Later dry weight was express as a percentage of the fresh weight of the sample taken. Biomass was determined by recording the weight of whole plant shoots and harvest index was estimated as the ratio of the storage root weight to the total biomass weight (shoots plus storage roots).

Data were analysed using the R statistical software (R Core Team 2019). With the agricolae package, means were separated using least significant difference (LSD) at 5 % probability. The effect of the different population densities on the performance of cassava and cowpea was determined using contrast analysis.

Results

Soil characteristics

The soil was a sandy loam with a pH of 5.68, organic carbon of 0.98% total nitrogen of 0.04%, available P of 4.24 mg/kg and exchangeable potassium of 37 mg/kg. Composition of sand, silt and clay were 64.96%, 26.88% and 8.16% respectively.

Performance of cassava as affected by intercropping with cowpea

Even though intercropped cassava had the tallest plants and widest canopy compared to sole cassava, analysis of variance indicated no significant ($p>0.05$) differences in the two variables at all the sampling stages in 2018 and 2019 (Tables 1 and 2). Results obtained in 2018 and 2019 for plant height showed that intercropping cassava with a cowpea population density of 332,000 plants/ha produced significantly ($p<0.05$) taller plants than those from intercropped cassava at cowpea population densities of 166,000 plants/ha and 110,000 plants/ha at all the sampling stages. However, apart from plant height at harvest in both cropping seasons and at 3 months after planting (MAP) in 2019, cassava intercropped at cowpea population density of 166,000 plants/ha was not significantly different from when cassava was intercropped with a cowpea population density of 110,000 plants/ha. The shortest plants were obtained when cassava was intercropped at cowpea population density of

110,000 plants/ha. Cassava intercropped with different cowpea population densities had significantly (p<0.05) different widths in both 2018 and 2019 (Tables 1 and 2). The widest canopies were obtained from cassava plots intercropped with cowpea population density of 332,000 plants/ha which was followed by intercropped cassava at cowpea population density of 166,000 plants/ha at all the sampling stages. However, apart from canopy width at 6 MAP in both years, it was not statistically different from intercropped cassava at cowpea population density of 166,000 plants/ha.

There was no significant (p>0.05) effect of cowpea variety on plant height of the cassava at the different sampling stages except at 6 MAP in 2018 and 6 MAP and at harvest in 2019 (Tables 1 and 2). However, the tallest plants were obtained when Kirkhouse Benga was intercropped with cassava. Apart from 6 MAP in 2018, there was no significant (p<0.05) effect of variety on canopy width and plant height in both 2018 and 2019 cropping seasons although, intercropping cassava with Kirkhouse Benga produced the widest canopy than cassava intercropped with Padi-tuya.

Table 1. Plant height and canopy width of cassava as influenced by cowpea population density in the 2018 cropping season

Treatment	Plant Height (cm)			Canopy Width (cm)		
	Months after Planting					
	3	**6**	**At harvest**	**3**	**6**	**At harvest**
Cropping systems						
Intercropped cassava	42.2	100.5	115.9	45.5	94.4	108.0
sole cassava	40.2	98.8	113.1	44.3	91.5	107.0
SE	21.73	30.83	9.42	16.69	14.33	22.98
Significance	NS	NS	NS	NS	NS	NS
Cowpea population density (plants/ha)						
Intercrop 1	37.1	98.1	114.3	42.5	89.3	104.9
Intercrop 2	40.0	92.1	106.5	44.7	95.1	105.0
Intercrop 3	49.6	111.2	126.7	49.5	98.8	114.2
SE	6.70	9.51	2.91	5.15	3.42	7.09
Significance	NS	*	**	NS	*	NS
Intercrop 1 vs Intercrop 2	NS	NS	***	NS	*	NS
Intercrop 1 vs Intercrop 3	**	*	***	*	**	*
Intercrop 2 vs Intercrop 3	*	**	***	NS	NS	*
Variety						
Cassava x Kirkhouse Benga	43.8	96.0	119.0	46.7	96.8	113.2
Cassava x Padi-tuya	40.6	105.0	112.7	44.4	92.0	102.9
SE	8.21	1.65	3.56	6.31	1.45	8.69
Significance	NS	*	NS	NS	*	NS

Intercrop 1 = Intercropped cassava at cowpea population density of 111,000 plants/ha; Intercrop 2 = Intercropped cassava at cowpea population density of 166,000 plants/ha; Intercrop 3 = Intercropped cassava at cowpea population density of 332,000 plants/ha. NS = Not signifncant (P> 0.05), * = significant (P< 0.05), ** = very significant (P< 0.01) and ***= highly significant (P< 0.001)

Table 2. Plant height and canopy width of cassava as influenced by cowpea population density in 2019 cropping season

Treatment	Plant Height (cm)			Canopy Width (cm)		
	Months after Planting					
	3	6	At harvest	3	6	At harvest
Cropping systems						
Intercropped cassava	33.3	109.8	137.2	33.4	102.1	120.4
sole cassava	32.8	107.8	133.5	32.1	101.0	115.3
SE	6.07	10.18	15.46	8.06	9.58	25.39
Significance	NS	NS	NS	NS	NS	NS
Cowpea population density (plants/ha)						
Intercrop 1	31.0	107.2	130.1	31.7	98.6	115.0
Intercrop 2	33.3	108.0	138.3	33.4	101.8	115.9
Intercrop 3	35.5	114.3	143.3	35.0	105.9	130.3
SE	0.87	2.14	4.77	2.49	1.47	7.84
Significance	*	*	*	NS	*	NS
Intercrop 1 vs Intercrop 2	*	NS	**	NS	*	NS
Intercrop 1 vs Intercrop 3	***	***	***	*	***	**
Intercrop 2 vs Intercrop 3	*	*	*	NS	*	**
Variety						
Cassava x Kirkhouse Benga	33.6	111.2	139.9	33.4	102.8	122.1
Cassava x Padi-tuya	32.9	108.5	134.6	33.3	101.4	118.7
SE	2.29	0.85	0.64	3.05	3.62	3.60
Significance	NS	*	*	NS	NS	NS

Intercrop 1 = Intercropped cassava at cowpea population density of 111,000 plants/ha; Intercrop 2 = Intercropped cassava at cowpea population density of 166,000 plants/ha; Intercrop 3 = Intercropped cassava at cowpea population density of 332,000 plants/ha. NS = Not signifncant (P> 0.05), * = significant (P< 0.05), ** = very significant (P< 0.01) and ***= highly significant (P< 0.001)

Effect of cropping system on storage root yield and yield components of cassava

Significant ($p<0.05$) effects of cropping system and cowpea population density were observed on root diameter, root length, root yield, dry matter and harvest index in both 2018 and 2019 (Table 3). However, with the exception of dry matter content, variety effects on the yield and yield components of cassava were not significant ($p>0.05$) in 2018 (Table 3). In 2018 and 2019, root diameter, root length, number of roots/plant, root yield, dry matter content and harvest index were significantly higher in the intercropped cassava than the sole cassava. Apart from dry matter content and root length, number of roots/plant and dry matter content in 2019, intercropped cassava at cowpea population density of 332,000 plants/ha was statistically (p<0.05) different from intercropped cassava at cowpea population density of 166,000 plants/ha and 110,000 plants/ha in both 2018 and 2019. The highest values (4.1 cm and 4.2 cm), (46.7 cm and 45.9 cm) and (12.6 roots/plant and 11.3 roots/plant) and were obtained for root diameter, root length and number of roots/plant in 2018 and 2019 respectively under 332,000 plants/ha. However, in 2019, intercropped cassava at cowpea population density of 332,000 plants/ha did not differ significantly from when cassava was intercropped at cowpea population density of 166,000 plants/ha for root length and number of roots/plant. The lowest values (3.7 cm and 3.5 cm), (43.0 cm and 40.6 cm) and (10.1 roots/plant and 8.6 roots/plant) and were obtained for root diameter, root length and number of roots/plant in 2018 and 2019 respectively when cassava was intercropped at cowpea population density of 332,000 plants/ha.

Table 3. Effect of cropping system and cowpea population density on storage root yield and yield components of cassava in 2018 and 2019 cropping seasons

Treatment	**Root diameter (cm)**		**Root length (cm)**		**Number of roots/plant**		**Root yield, (t/ha)**		**Dry matter content (%)**		**Harvest index**	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Cropping systems												
Intercropped cassava	3.9	3.8	44.2	43.8	12.3	10.1	25.6	24.3	34.5	40.0	0.65	0.56
Sole cassava	3.4	3.3	41.0	34.8	8.6	8.1	22.4	18.6	32.6	32.5	0.57	0.51
SE	0.22	0.15	0.15	3.67	1.21	0.33	1.25	1.11	0.40	2.17	0.02	0.02
Significance	**	**	**	***	***	**	*	**	*	**	**	*
Cowpea population density												
Intercrop 1	3.7	3.5	43.0	40.6	10.1	8.6	19.7	21.4	32.9	36.8	0.59	0.47
Intercrop 2	3.8	3.9	43.1	45.0	11.3	10.4	26.2	24.1	33.9	40.6	0.64	0.55
Intercrop 3	4.1	4.2	46.7	45.9	12.6	11.3	30.9	27.5	36.6	42.7	0.70	0.66
SE	0.26	0.31	1.72	2.98	0.90	0.93	2.73	1.93	1.36	3.45	0.02	0.04
Significance	NS	*	*	NS	*	*	*	*	NS	NS	**	*
Intercrop 1**vs** Intercrop 2	NS	*	NS	*	*	*	***	*	NS	*	**	**
Intercrop 1**vs** intercrop 3	**	***	**	**	***	**	***	***	***	**	***	***
Intercrop 2**vs** intercrop 3	*	*	**	NS	*	NS	**	**	**	NS	**	***
Variety												
Cassava x Kirkhouse Benga	3.8	3.9	44.6	44.1	11.4	10.2	26.6	24.8	35.4	39.5	0.66	0.57
Cassava x Padi-tuya	3.9	3.7	43.9	43.5	11.2	10	24.6	23.9	33.5	40.5	0.64	0.55
SE	0.33	0.38	2.11	3.65	1.21	1.59	3.35	2.37	1.66	4.22	0.03	0.05
Significance	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS

Intercrop 1 = Intercropped cassava at cowpea population density of 111,000 plants/ha; Intercrop 2 = Intercropped cassava at cowpea population density of 166,000 plants/ha; Intercrop 3 = Intercropped cassava at cowpea population density of 332,000 plants/ha. NS = Not signifncant (P> 0.05), * = significant (P< 0.05), ** = very significant (P< 0.01) and ***= highly significant (P< 0.001)

Significantly, the highest root yields of 30.9 t/ha and 27.5 t/ha were obtained when cassava was intercropped at cowpea population density of 332,000 plants/ha in 2018 and 2019 respectively. The lowest root yields (19.7 t/ha and 21.4 t/ha) were recorded under intercropped cassava at cowpea population density of 110,000 plants/ha in 2018 and 2019 respectively. The highest dry matter values (36.6% and 42.7%) and harvest index (0.70 and 0.66) in 2018 and 2019 respectively were obtained when cassava was intercropped at cowpea population density of 332,000 plants/ha. However, in 2019, dry matter content under 332,000 plants/ha was not significantly different from 116,000 plants/ha whilst the least values (32.9% and 36.8%) and (0.59 and 0.47) were obtained by dry matter content and harvest index in 2018 and 2019 under intercropped cassava at cowpea population density of 110,000 plants/ha respectively. Apart from dry matter content in 2018, variety did not significantly ($p<0.05$) influence any of the yield parameters measured. Dry matter content was significantly higher when cassava was intercropped with Kirkhouse Benga than with Padi-tuya (Table 3).

Cowpea components as affected by intercropping with cassava

Apart from biomass yield in both 2018 and 2019, intercropping had no significant effect on plant height, nodule number, number of pods/plant, number of seeds/pod and grain yield (Tables 4 and 5). Intercropped cowpea produced significantly ($p< 0.05$) greater biomass yield (3617.5 kg/ha and 2149.8 kg/ha) in 2018 and 2019 respectively compared to the sole cowpea (2769.3 kg/ha and 1978.9 kg/ha). In 2018, with the exception of biomass yield, intercropped cassava at cowpea population density of 166,000 plants/ha differed significantly ($p< 0.05$) from intercropped cassava at cowpea population density of 110,000 plants/ha and 332,000 plants/ha for plant height at harvest, number of pods per plant, number of seeds per pod and grain yield in 2019 (Tables 4 and 5. However, in 2019 it was not significantly ($p> 0.05$) different from intercropped cassava at cowpea population density of 110,000 plants/ha with respect to plant height at harvest, number of nodules per plant, number of pods per plant, number of seeds per pod and grain yield. Significantly, the tallest plants (86.6 cm and 56.5 cm) were produced when cassava was intercropped at cowpea population density of 332,000 plants/ha in 2018 and 2019 respectively whilst the shortest plants (58.0 cm and 46.0 cm) were obtained when cassava was intercropped at cowpea population density of 110,000 plants/ha. Intercropped cassava at cowpea population density of 166,000 plants/ha had significantly more nodules per plant in both years compared with intercropped cassava at cowpea population density of 110,000 plants/ha and 332,000 plants/ha. The lowest numbers of nodules per plant were recorded when cassava was intercropped at cowpea population density of 110,000 plants/ha in both years. The highest numbers of pods per plant for 2018 and 2019 respectively (9.2 pods/plant and 12.5 pods/plant) were obtained under intercropped cassava at cowpea population density of 166,000 plants/ha though not significantly different from when cassava was intercropped at cowpea population density of 110,000 plants/ha in 2019. The least number of pods/plant (8.1 pods/plant and 10.8 pods/plant) for 2018 and 201 respectively, were obtained 332,000 plants/ha. Significantly higher number of seeds (7.3 seeds/pod and 7.9 seeds/pod) were obtained under intercropped cassava at cowpea population density of 166,000 plants/ha in 2018 and 2019 respectively. However, in 2019 it was not significantly different from intercropped cassava at cowpea population density of 110,000 plants/ha. The lowest numbers of seeds per pod (5.5 seeds/plant and 6.0 seeds/plant) were obtained when cassava was intercropped with cowpea at cowpea population density of 332,000 plants/ha in 2018 and 2019 respectively.

Table 4. Effect of cropping system and population density on growth and yield components of cowpea in the 2018 cropping season

Treatment	Plant height at harvest (cm)	Number of nodules/plant	Number of pods/plant	Number of seeds/ pod	Grain yield (kg/ ha)	Biomass yield (kg/ ha)
Cropping systems						
Intercropped cowpea	70.2	15.8	8.7	6.9	1096.5	3617.5
Sole cowpea	73.3	16.2	8.4	5.8	1116.0	2763.7
SE	14.4	2.82	1.89	1.91	73.8	455.0
Significance	NS	NS	NS	NS	NS	*
Cowpea population density (plants/ha)						
Intercrop 1	58.0	16.2	8.3	6.4	1092.9	2958.4
Intercrop 2	70.5	18.2	9.2	7.3	1161.1	2588.0
Intercrop3	86.6	13.7	8.1	5.5	1064.7	4033.8
SE	11.5	2.31	1.55	1.56	60.30	1177.0
Significance	*	NS	NS	NS	NS	NS
Intercrop 1 vs intercrop 2	***	**	*	*	***	NS
Intercrop 1 vs intercrop 3	***	***	NS	*	NS	*
Intercrop 2 vs Intercrop 3	***	***	**	***	***	**
Variety						
Cassava x Kirkhouse Benga	70.1	16.0	8.7	6.9	1112.7	3398.8
Cassava x Padi-tuya	73.4	16.1	8.4	5.8	1099.8	2982.5
SE	14.1	2.82	1.89	1.91	73.8	1466.0
Significance	NS	NS	NS	**	NS	NS

Intercrop 1 = Intercropped cassava at cowpea population density of 111,000 plants/ha; Intercrop 2 = Intercrop cassava at cowpea population density of 166,000 plants/ha; Intercrop 3 = Intercrop cassava at cowpea population density of 332,000 plants/ha. NS = Not signifncant (P> 0.05), * = significant (P< 0.05), ** = very significant (P< 0.01) and ***= highly significant (P< 0.001)

Table 5. Effect of cropping system and population density on growth and yield components of cowpea in the 2019 cropping season

Treatment	Plant height at harvest	Number of nodules plant per plant	Number of pods per plant	Number of seeds per pod	Grain yield (kg/ha)	Biomass yield (kg/ha)
Cropping systems						
Intercropped cowpea	50.0	15.3	11.1	7.2	1217.3	2149.8
sole cowpea	51.1	16.7	12.0	6.6	1292.9	1978.9
SE	8.94	6.04	4.24	3.95	675.0	85.0
Significance	NS	NS	NS	NS	NS	**
Cowpea population density (plants/ha)						
Intercrop 1	46.0	15.9	11.2	6.3	1278.4	1559.2
Intercrop,2	49.2	18.8	12.5	7.9	1533.6	2220.9
Intercrop 3	56.5	13.8	10.8	6.0	953.4	2413.0
SE	7.30	4.94	3.46	3.23	551.0	290.0
Significance	NS	NS	NS	NS	NS	***
Intercrop 1 vs intercrop 2	NS	*	NS	NS	NS	***
Intercrop 1 vs Intercrop 3	***	*	NS	NS	*	***
Intercrop 2 vs Intercrop 3	***	***	*	*	***	*
Variety						
Cassava x Kirkhouse Benga	46.5	15.4	11.6	6.8	1336.9	2156.3
Cassava x Padi-tuya	54.6	16.6	11.4	6.6	1173.4	1972.4
SE	8.94	6.04	4.24	3.95	675.0	92.0
Significance	***	NS	NS	NS	NS	**

Intercrop 1 = Intercropped cassava at cowpea population density of 111,000 plants/ha; Intercropped 2 = Intercrop cassava at cowpea population density of 166,000 plants/ha; Intercropped 3 = Intercrop cassava at cowpea population density of 332,000 plants/ha. NS = Not signifncant (P> 0.05), * = significant (P< 0.05), ** = very significant (P< 0.01) and ***= highly significant (P< 0.001)

The highest grain yields of 1161.1 kg/ha and 1533.6 kg/ha were obtained at cowpea population density of 166,000 plants/ha under intercropped cassava in 2018 and 2019 respectively (Tables 4 and 5). However, it was not significantly different from intercropped cassava at cowpea population density of 110,000 plants/ha in 2019. The lowest grain yields (1064.7 kg/ha and 953.4 kg/ha) were obtained under intercropped cassava at cowpea population density of 332,000 plants/ha in both 2018 and 2019 respectively. Biomass yields of cowpea (4033.8 kg/ha and 2413.0 kg/ha) were significantly higher in 2018 and 2019 cropping season respectively when cowpea was intercropped with cassava at cowpea population density of 332,000 plants/ha. The lowest biomass yields (2588.0 and 1559.2 kg/ha) were obtained under intercropped cassava at cowpea population density of 166,000 plants/ha in 2018 and 110,000 plants/ha in 2019 respectively.

There was no significant effect of variety on all the growth and yield attributes measured in this studies apart from number of seeds per pod in 2018, plant height at harvest and biomass yield in 2019 (Tabless 4 and 5). Kirkhouse Benga produced significantly greater number of seeds per pod (7 seeds/pod) compared to Padi-tuya in 2018. In 2019, Padi-tuya significantly produced taller plants (54.6 cm) than Kirkhouse Benga. The highest biomass yield (3398.8 and 2156.3 kg/ha) was obtained from Kirkhouse Benga in 2018 and 2019 cropping seasons respectively whilst Padi-tuya had the lowest (2982.5 and 1972.4 kg/ha) in 2018 and 2019 respectively.

Land equivalent ratio (LER) in cassava/cowpea intercropping system

Intercropped cassava at cowpea population density of 332,000 plants/ha had the highest value of total LER (1.32) in 2018 whilst highest value of 2.42 was observed in intercropped cassava at cowpea population density of 166,000 plants/ha in 2019 (Table 6). The lowest total LER values of 1.84 and 2.13 were obtained under intercropped cassava at cowpea population density of 111,000 plants/ha in 2018 and 2019 respectively. Intercropping reduced the yield of cowpea and increased the yield of cassava as partial LER for both crops showed that the contribution to the total LER was more from the cassava in both years than cowpea except in 2018 when intercropped cassava at cowpea population density of 111,000 plants/ha had more partial LER (0.97) than cassava (0.87).

Table 6. Effect of cowpea population density on land equivalent ratio (LER) in cassava-cowpea intercrop

	Land equivalent ratio (LER)					
Cowpea population density(plants/ha)	**2018**			**2019**		**Total LER**
	Partial LER			**Partial LER**		
	Cassava	Cowpea		Cassava	Cowpea	
Sole cassava	1	-	1	1	-	1
Sole cowpea	-	1	1	-	1	1
111,000 + cassava	0.87	0.97	1.84	1.15	0.98	2.13
166,000 + cassava	1.16	1.04	2.25	1.29	1.18	2.42
332,000 + cassava	1.37	0.97	2.32	1.47	0.73	2.2

Discussion

This study was carried out to assess the storage root yield of cassava as influenced by intercropping with cowpea. It was found that intercropping had significant effect on the storage root yield and yield components of cassava but similar growth rate of the cassava was observed under the intercropped and sole cassava. For instance, the plant heights of cassava in the sole cropping system and when intercropped with cowpea were similar, suggesting that the presence of the cowpea in cassava had no negative influence on the plant height of cassava. Njoku and Muoneke (2008) obtained similar results in a cassava/cowpea intercrop and attributed it to the different growth habits of the two crop species. There was significant effect of intercropping on number of storage roots per plant, diameter and length of storage roots as well as storage root yield (t/ha). The intercropped cassava produced higher root yield compared to the sole cassava, similar to the findings of Mbah (2018). Though the intercropped cassavafaced initial competition from the cowpea, the cassava had ample time to recover after harvesting of the cowpea and also benefited from the organic matter and fixed nitrogen left by the cowpea residue after harvesting of the podsBesides, the cowpea could have maintained a good cover of the soil thereby minimizing erosion and improving crop performance.

The intercropped cassava had significantly higher storage root dry matter content and harvest index than the sole cassava indicating that more photosynthates were translocated to the economic part thereby resulting in greater yields in both cropping seasons. Harvest index is one of the most important attributes of crop improvement which gives an indiction of the proportion of biomass that is traslocted into the economic part. De Souza *et al.* (2017) indicated that one of the key factors that positively championed the increased yields during the green evolution era was improvement in harvest index. Grain yields of wheat and rice were significantly improved with increase in harvest index of these crops. Generally increasing the population density of cowpea increased plant height of the intercropped cassava. The results from this study corroborate the findings of Muoneke and Mba (2007) who also observed increased plant height of cassava when the population density of the intercropped okra was progressively increased up to 56,000 plants/ha. According to Leihner (1983), cassava has a wide range of growth habits which may influence the amount of solar radiation interception during growth. This suggests that with high plant vigour and early branching cassava varieties, there can be faster growth, and hence wider canopy spread. In this study, intercropping increased storage root length, storage root diameter, number of storage roots/plant and storage root yield (t/ha) in both cropping seasons. This could be due to better photosynthetic efficiency by the intercropped than the sole cassava. Number, length and diameter of storage roots increased with increase in cowpea plant populations. These findings agree with the observations of Mbah and Ogidi (2012) in cassava-soybean intercrop study. It was found that higher number and bigger roots/plant were obtained under the higher soybean plant population of 332,000 plants/ha. They pointed out that cassava storage root initiation and bulking were not subjected to any intercrop competition since the soybean was harvested before peak storage root bulking. Earlier studies have indicated that storage root number, length and diameter were the main yield components contributing to yield increase in cassava (Teye *et al*., 2011; Agahiu *et al*., 2011). In the current study, intercropped cassava at a higher cowpea population density (332,000 plants/ha) produced longer roots and bigger roots per plant, which eventually resulted in higher yield of cassava compared to the sole cassava.

Cassava root yield increased when it was intercropped at the highest cowpea population density which confirms an earlier work done by Njoku and Muoneke (2008), who attributed it to the fact that, cowpea being a legume is able to fix nitrogen for uptake by the cassava thereby improving the soil nutrient status which eventually resulted in the higher yield of the cassava under the intercrop system. Furthermore, Makinde *et al*. (2007), working on cassava-soybean intercropping, found that the incorporation of residues of a leguminous plant like soybean resulted in 10 to 23 % yield increase in cassava. Dry matter content was high under intercropped cassava at the highest cowpea population density. This might have contributed to the high yield obtained under the intercropped cowpea at the high population density. Adjebeng-Danquah *et al*. (2012) indicated that in yield estimation of cassava, more emphasis should be placed on storage root dry matter content instead of root sizes and fresh root yield. Harvest index which reflects the efficiency in dry matter partitioning to the economically important parts also increased when cassava was intercropped at the highest cowpea plant population. Cropping system did not have any significant effect on plant height, number of nodules/plant, number of pods/plant, number of seeds/pod and grain yield of cowpea except for biomass yield in both cropping season. The non-significant effect of cropping system on plant height might be due to less shading effect of cassava and competition on the intercropped cowpea. This corroborates the findings of Njoku and Muoneke (2008) who reported that plant height of cowpea did not give significant response to cassava/cowpea intercropping. Similar results had also been reported by Sibhatu *et al*. (2015) in sorghum/cowpea and Abraha (2013) in lablab/maize intercropping system. The sole cowpea produced greater number of nodules though not significantly different from the intercropped cowpea. This observation was contrary to the findings of Sibhatu *et al*. (2015) who reported that cropping system significantly influenced the nodule number plant/plant of cowpea in sorghum/cowpea intercrop. They attributed the low nodule number in intercropped cowpea to the shading effect of sorghum that hinders N-fixation. Intercropping had no significant effect on number of pods/plant of cowpea which is similar to the findings of Solomon *et al.* (2014) who reported a non-significant effect of intercropping on number of pods/plant in maize- soybean intercropping system.

The number of seeds/pod of intercropped cowpea was not significantly affected by intercropping system which is similar to the findings of Minale *et al.* (2001) in maize-faba bean intercropping. Again, intercropping did not significantly reduce grain yield/ha of cowpea in both seasons. This might be due to the enhanced compatibility of the cowpea and cassava as intercrop partners during the slow initial growth phase of cassava which posed less competition with the cowpea (Njoku and Muoneke, 2008). However, this contradicts the observations of Omae *et al*. (2014) in a millet-cowpea intercropping study where cowpea planting density affected grain yield of intercropped cowpea. Biomass yield was significantly higher in the intercrop cowpea plots compared to the sole plantings in both years. Sibhatu *et al.* (2015), working on sorghum-cowpea intercropping system however, observed significantly higher biomass yield under the sole planting compared to the intercrop. This was attributed to the absence of or less competition which resulted in more dry matter accumulation in the above ground biomass. The current observations further agree with the findings of Bekele *et al*. (2013) who asserted that dry biomass of forage legumes was significantly affected when intercropped with maize. Plant height of cowpea was also significantly higher with intercropped cassava at higher population density of cowpea. They attributed this to etiolation which might have possibly arisen due to competition for resources such as moisture, soil nutrients and light. In the case of the cowpea, it was found that number of nodules/plant, number of pods/plant, number of seeds/pod and grain yield (kg/ha) increased under intercropping with cassava and with increasing cowpea population density up to 166,000 plants/ha but then decreased with further increase in plant density. This is consistent with the findings of Mbah and Ogidi (2012) in cassava-soybean intercrop. The results further conform with the observations of Adeniyan *et al.* (2014) who reported increased grain yield with increased plant population density from 20,000 plants/ha to 40,000 plants/ha though further increase in plant population up to 80,000 plants/ha resulted in lower grain yield of soybean. The higher biomass yield of cowpea observed under intercropping with cassava in this study at higher cowpea population density (332,000 plants/ha) might be due to the high vegetative growth resulting from increased competition for light and other resources (Masa *et al*., 2017).

Varietal effect was not significant for plant height, nodule number, pod number, seed number as well as grain and biomass yields in both years except for seed number in 2018 and plant height and biomass yield in 2019. Intercropped Padi-tuya produced taller plants compared to Kirkhouse Benga intercropped with cassava in both cropping seasons. This could be due to the inherent variation resulting from interaction between genes within the two varieties (Misganaw and Demisie Bayou, 2020). Furthermore, it could also be due to competition and shading effect of the competitive abilities of the component crops for light and other resources. Grain yield under intercropping was greater in Kirkhouse Benga than Padi-Tuya and could be due to the competitive ability and compatibility of Kirkhouse Benga with the cassava intercrop partner compared to Padi-tuya intercropped with cassava. Kirkhouse Benga produced greater biomass when intercropped with cassava than Padi-tuya indicating better compatibility with cassava than Padi-tuya. The observed partial LER of cassava was higher under almost all the cowpea population densities indicating the greater competitive ability of cassva compared to cowpea (Njoku and Muoneke, 2008).

It can be concluded that intercropping cassava with cowpea improves cassava root yield compared with sole cassava. The growth traits and the yield components were significantly influenced by cowpea varietal effect. Intercropped cowpea at population densities of 332,000 and 166,000 produced significantly higher biomass than cowpea population of 110,000 plants/ha in intercropped system with cassava. Intercropping cassava with cowpea population of 332,000 plants/ha can significantly increase the storage root yield of cassava.

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