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GROWTH AND YIELD RESPONSE OF NEWLY RELEASED CASSAVA GENOTYPES AND HYBRID MAIZE TO INTERCROPPING

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Abstract

Cassava/maize intercrops have been reported to be highly productive, mainly because of their different growth patterns. However, there is limited information on the influence of maize planting density in the cassava/maize intercrop on the performance of hybrid maize and improved cassava genotypes in Uganda. Thus, this study determined whether recently released cassava genotypes which are selected on the basis of monocrop performance, would perform equally well when intercropped with hybrid maize varieties. Cassava genotypes NAROCASS 1 and NASE 14 intercropped with Longe 6H maize were evaluated using randomized complete block design and three replications. Treatments were: Sole maize (SM), sole cassava (SC), alternate rows of cassava and maize (1C:1M), and one row of cassava alternating with two rows of maize (1C:2M). Intercropping significantly increased the maize plant heights in the 1C:2M system than in sole maize. Cob length and number of rows per cob decreased as the plant population density increased. Maize grain yield under the 1C:1M system was comparable to that of sole cropping. The 1C:2M system gave significantly reduced grain yields when compared with those at 1C:1M. Cassava root yield decreased in the order (SM>1C:1M>1C:2M). Although the yields of both cassava and maize under sole cropping were higher than their intercrop counterparts, intercropping was more productive than sole cropping as evidenced by the land equivalent ratios.

Keywords: Crop Yield; Land Equivalent Ratio; Manihot Esculenta; Plant Density; Sole Cropping.

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1. Introduction

Cassava (*Manihot esculenta* Crantz) is a shrubby and tuberous perennial plant that produces long and tapered storage roots that are a major source of carbohydrates for humans. Depending on the cultivar and growing conditions, these large storage roots are harvested between six and 24 months

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after planting [MAP] (Alves, 2002). According to Nweke *et al*. (1999), the roots can remain in the soil for one to two years without rotting, particularly under drought conditions. Cassava is one of the most important staple foods in Uganda, next to rice and maize (USAID 2010). In Uganda, cassava is currently ranked second to bananas, providing around 13% of the daily caloric intake (Bua *et al*., 2012). The FAOSTAT data further shows that whereas Uganda had the fifth largest cassava area harvested in 2014, its production in metric tons (MT) was ranked as the 12th largest in Africa. Whilst the area planted had more or less doubled between 2012 and 2014, the root yield per hectare dropped from 12 MT in 2010/11 to approximately 4 MT in 2012 (FAO, 2014).

Cassava's rising demand for food, feed and industrial purposes is driving the need to increase its production. While farmers already consider cassava as a major staple food crop, it has the potential to be an important part of the solution to improving food security in times of climate change and declining soil fertility (El-Sharkawy and Cadavid, 2003). However, many years of inadequate attention have tagged cassava as the "poor man's crop". Ironically, cassava's on-going contribution to food security and its many industrial uses amounts to a large and positive impact on economic and industrial development.

Despite its importance, cassava yields per unit area in Uganda are relatively low; averaging to 12.6 MT/ha compared to the yield potential of 25.5 MT/ha (Fermont *et al*., 2008). The reasons for this wide yield gap include the planting of low yielding varieties, soil infertility, inadequate use of inputs such as mineral fertilizers, damage by pests and diseases notably cassava mosaic disease and cassava brown streak disease (Fermont *et al*., 2008; Pypers *et al*., 2011) and unpredictable climatic conditions such as floods and droughts (MAAIF/FAO, 2011). However, there are several ongoing interventions to address these constraints. In Uganda, improved cassava varieties have been developed and released so as to meet the ever growing demand for cassava (NARO, 2016). In areas where improved varieties have been introduced and farmers trained on how to control major cassava diseases, yields have tremendously increased. Other alternatives that have been proposed to improve and sustain cassava production include the use of inorganic fertilizers (FAO, 2013), and the application of carefully designed cropping systems (Okalebo *et al*., 2006). In fact, intercropping is the principle means of intensifying crop production as well as improving returns from limited land holdings.

Cassava and maize are prominent crops under intercropping systems, and have been extensively studied in many African countries. The cassava/maize intercrops have been reported to be highly productive and compatible, mainly because maize is a short season crop while cassava is a long duration crop (Ikeorgu, 2002). However, there is limited information on the influence of planting density of maize in the cassava/maize intercrop on the performance of hybrid maize and improved cassava genotypes in Uganda. Yet, sustainable cassava production depends on the use of genotypes adapted to the environment together with intercropping and fertilizer application (Zinsou *et al*., 2004). This study, therefore, was undertaken to fill this gap. Specifically, the study determined whether the newly released cassava varieties which are selected on the basis of monocrop performance, would perform equally well when intercropped with hybrid maize varieties, and also assessed the land productivity under cassava/maize intercropping.

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1.1. Effect of Plant Population Density and Intercropping on Yield Performance

Plant populations are important in determining yield and competition for the available resources. Some crop varieties, however, have a high degree of plasticity and such varieties give fairly stable yield over a wide range of populations and on intercropping such varieties, the population effect on yield is low compared to its sole stand. Carsky and Toukourou (2005) reported that two plants no matter how close do not compete with each other as long as the water content, the nutrient material, light and space are in excess of the needs of both. In addition, Quansah *et al*. (1998) reported that the level of competition depended on the level of supply of resources, the nature of the plant community in particular the resource requirements of the individual plants, the number of plants per unit area (plant population) and the spatial arrangements. Carsky and Toukourou (2005) suggested that as population of monocultures are increased, competition is likely to begin earlier than for different species because in a monoculture all the plants require the same resources at the same time. Willey and Osiru (1972) suggested that intercrops required different resources and competition was less likely, and optimum population for intercrops was higher since the intercrops had the ability to make better use of environmental resources. This was further supported by the research of Adeniyan et al. (2010) who pointed out that maize in pure stand yielded best at 75 x 50 cm spacing, but under intercropping, the best yield was obtained at 75 x 30 cm spacing in a cassava/maize intercrop. It therefore follows that the extent to which the population must be increased should be related to the magnitude of the yield advantages (Ayoola *et al*., 2007b).

1.2. Land Equivalent Ratio

Land Equivalent Ratio (LER) defined as the total land area required under sole cropping to yields obtained in the intercropping (Mead and Willey, 1980). Land equivalent ratio shows the efficiency of intercropping for using the environmental resources compared with monocropping with the value of unity to be the critical. When the LER is greater than one (unity) the intercropping favors the growth and yield of the species, whereas when the LER is lower than one the intercropping negatively affects the growth and yield of the plants grown in mixtures (Willey and Natarajan, 1980). Asynchrony in resource demand ensures that the late maturing crop can recover from possible damage caused by a quick-maturing crop component and the available resources, e.g. radiation capture over time, are used thoroughly until the end of the growing season (Keating and Carberry, 1993).

Land equivalent ratio is one of the most important reasons for growing two or more crops simultaneously is to ensure that an increased and diverse productivity per unit area is obtained compared to sole cropping. An assessment of land return is made from the yield of pure stands and from each separate crop within the mixture. The calculated figure is called the LER, where intercrop yields are divided by the pure stand yields for each crop in the intercropping system and the two figures added together (Sullivan, 2003).

Yield advantages from intercropping as compared to sole cropping, are often attributed to mutual complementary effects of component crops, such as better and total use of available resources (Ayola and Makinde, 2007a). Generally, sole maize has higher yields compared to yields in an intercropping system. However, in most cases, land productivity measured by LER clearly shows

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the advantage of mixed cropping of cereals and cassava (Yunusa, 1989). The land use efficiency measured by relative yields increased with increasing maize population. Planting cassava and maize in the same row, inter-row and alternate row arrangements had no significant effect on maize grain or on cassava root yields, the earliness of maize maturity notwithstanding (Ayola and Makinde, 2007b).

Due to a compensatory relationship in the yields of cassava and maize intercropping systems, the choice of an appropriate maize variety and maize population in cassava and maize intercrop system will depend on the relative importance to a farmer of the two crops (Ezumah *et al*., 1988). Muoneke *et al.* (2007) found that the productivity of the intercropping system indicated yield advantage of 2.63% as depicted by the LER of 1.02-1.63 showing efficient utilization of land resource by growing the crops together. Land equivalent ratio gives an indication of magnitude of sole cropping required to produce the same yield on a unit of intercropped land and research results indicate that response of nitrogen to intercropping generally results in reduced LER values. However, when two intercrops are using the same growth resource, a decrease in yield of one crop could be expected, especially when one crop is more competitive than the other. Limitations to the use of the LER concept should also be realized, particularly when used to compare the productivity of an intercrop and sole crop. Willey (1979) stated that one major problem is that the computation of LER needs maximum yields of sole crops obtained at optimum plant densities. When yields of sole crops at recommended densities are compared with those of intercrops, it will be likely that the advantage of intercropping is overestimated since density may be altered as an experimental variable to determine the optimum density overestimated (Hamid and Haque, 2001).

2. Materials and Methods

2.1. Experimental Site

Two field experiments were conducted during the first and second rains of 2015 at Kyambogo University Farm which is located on the eastern side of the university main campus at an altitude of 1189 meters above sea level, at coordinates 0°20'54" N and 32°37'49" E (Latitude 0.348334 and Longitude 32.630275). (https://en.wikipedia.org/wiki/Kyambogo). The soils are dark, reddish brown, sandy loams. To assess the status of the soil prior planting, soil samples were randomly collected from the trial site and analysed for chemical properties (Available N, extractable P and exchangeable K contents and pH) and physical properties (silt, sand and clay contents) according to standard methods described by Okalebo *et al*. (2002) (Table 1). Soil pH was measured in a soil water solution ratio of 1:2.5. Organic matter content was analyzed using the potassium dichromate wet acid oxidation method. Total N was determined by Kjeldhal digestion method, extractable P by Bray P1 method and exchangeable K from an ammonium acetate extract by flame photometry. Particle size distribution (texture) was determined using the Bouyoucos (hydrometer) method.

Table 1: Physical and chemical properties of soil on the experimental site

Soil Property	**0 – 15 cm**
Organic carbon (%)	2.27
Total nitrogen (%)	0.12
Exchangeable potassium (Cmol/kg)	0.38
Available phosphorus (mg/kg)	4.96
Soil pH	6.8

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Clay (%)	19
Silt (%)	12
Sand (%)	71
Soil textural class	Sandy loam
Soil structural class	Sub-angular blocky

2.2. Experimental Design and Treatments

The experimental design was Randomized Complete Block Design (RCBD) arranged as factorial with three replications. The treatments comprised: sole maize (SM) and sole cassava (SC) [T1], an intercrop of one row of cassava (NASE 14 / NAROCASS 1) to one row of maize (1C:1M) [T2] and an intercrop of one row of cassava (NASE 14 / NAROCASS 1) to two rows of maize (1C:2M) [T3]. Newly developed cassava genotypes NASE 14 and NAROCASS 1 formed the main plots and cropping system formed sub-plots of size was 4 x 5 metres. The field was marked into blocks and plots with one metre width alleys in between to enhance easy movement and agronomic operations.

2.3. Data Collection

For the maize component, data was collected on plant height at two and three months after planting (MAP), tasseling and at harvest, cob length, number of rows per cob, grain yield and grain weight. Data on cassava component was collected on plant height at two MAP, at branching and at harvest, root circumference, root length, number of saleable roots per plant and weight of saleable roots per hectare. The data at harvest were collected from the net plot. Measurements of cassava plant heights were taken from the base of the plant to the point of the first branch, and then to the tip of the terminal bud of each plant with a flexible measuring tape. The number of root per plant was determined by counting the tubers big enough to be consumed and marketed. Root diameter/girth was determined by measuring circumference of roots from the mid region of each tuber using thread and later confirmed with a metre ruler in centimetre. The length of each root was taken from the point of attachment to the stem up to the end point of the tuber using a tape. Fresh tuber weight was determined by weighing tubers using a weighing scale. Total root tuber yield per plot was determined by weighing all the root tubers from the plot and converting the weight into metric ton/hectare (MT/ha).

2.4. Assessment of Measures of Intercrop Productivity

The land equivalent ratio (LER) was calculated using the following formula developed by Mead and Willey (1985) and Willey and Rao (1980).

$$\mathbf{LER} = \frac{Y^*C\,i}{Y^*Cm} + \frac{Y^*Mi}{Y^*Mm}$$

Where: Y^*Ci = yield of cassava in the intercrop, Y^*Cm = yield of cassava in the monocrop, Y^*Mi = yield of maize in the intercrop and Y^*Mm = yield of maize in the monocrop.

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2.5. Statistical Analysis of Data

Data collected were subjected to analysis of variance (ANOVA) using Genstat Statistical Package (Version 12). Treatment means were compared using the Least Significant Difference (LSD) at 5% level of significance. Mean comparisons were made by Duncan Multiple Range Test (DMRT) when F-ratio was significant (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Hybrid Maize Response to Intercropping

3.1.1. Plant Heights

Results indicate that there were significant differences ($P<0.05$) in plant heights among the treatments at all stages of maize growth except at three months after planting (Table 2). But, the interaction effect between cassava genotypes and plant population densities on maize heights was not significant ($P>0.05$). In the NAROCASS I / Maize intercrop, maize plants at 2 MAP (MH_2), at tasseling (MHT) and at harvest (MHH) under the intercropping system 1C:2M were significantly ($P<0.05$) taller than those of maize plants under sole maize cropping system (Table 2). For the case of NASE 14/Maize intercrops, the same trend was observed only at 2 MAP, while there were no differences ($P>0.05$) at the rest of the growth stages. Intercropping significantly increased the maize plant heights in the 1C:2M intercropping system than in sole maize for the NAROCASS 1/Maize. This increase in the maize heights could be due to competition among the plants for light which made the maize plants in the intercrops to channel assimilates to the growth of maize stems. Similar observations were reported by Adeniyan *et al*. (2014), Sangakara *et al*. (2004) and Kaizzi (2002). Zamir *et al*. (2011) also reported an increase in plant height following the increase in plant density and they related this to the increase in inter-plant competition for light and the disruption of the balance of growth regulators. Under these conditions, plant height increases if other environmental factors, such as moisture and soil fertility are not limiting.

Table 2: Effect of cassava/maize intercrop on maize plant height

	NAROCASS I / Maize intercrop				**NASE 14 / Maize intercrop**			
Treatment	**MH_2**	**MH_3**	**MHT**	**MHH**	**MH_2**	**MH_3**	**MHT**	**MHH**
1C:1M	35.73^{ab}	135.0	171.87^{ab}	273.60^{a}	35.18^{ab}	126.0	165.80	259.20
1C:2M	38.40^{b}	158.0	128.70^{a}	327.80^{b}	37.27^{b}	155.0	172.10	303.20
SM	29.50^{a}	156.0	192.20^{b}	250.30^{a}	29.67^{a}	137.0	182.40	277.50
F-Prob.	0.002	0.618	0.004	<.001				
Mean	34.29	142.0	160.7	265.3				
$LSD_{(0.05)}$	6.28	75.8 NS	48.95	48.83				

^{abc}=Means within the same column having different superscripts are significantly ($P\leq0.05$) different from each other. MH_2= Maize height at 2 MAP, MH_3= Maize height at 3 MAP, MHT= Maize height at tasseling, MHH= Maize height at harvest, 1C:1M= Intercropping one row of cassava to one row of maize, 1C:2M= Intercropping one row of cassava to two rows of maize, SM = Sole maize, $LSD_{(0.05)}$ = Least Significant Difference at 5% level of significance.

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3.1.2. Maize Cob Length

There were significant differences (P<0.05) in maize cob length for both cassava/Maize intercrops (Table 3). Similarly, the interaction between plant density and cassava varieties was significant (P<0.05) for maize cob length. The lengths of cobs from sole maize cropping were higher (P<0.05) than those of cobs obtained from the 1C:2M intercropping. The higher cob length at lower plant population densities of sole maize (SM) could be attributed to lower competition for growth resources particularly nutrients, water and light. Lower competition allowed maize plants to accumulate biomass with higher capacity to make assimilates for depositing into the sinks resulting in longer cobs. These results are in conformity with those reported by Moges (2015) and Al-Naggar *et al.* (2015).

Table 3: Effect of cassava/maize intercrop on the yield components of maize

	NAROCASS I / Maize intercrop				**NASE 14 / Maize intercrop**			
Treatment	**MCL**	**MRPC**	**MGW**	**MGY**	**MCL**	**MRPC**	**MGW**	**MGY**
1C:1M	24.80	14.80b	2049.0a	1922.0c	23.73ab	14.90b	2050.0a	2215.0c
1C:2M	23.77	10.50a	2025.0a	1011.0a	22.50a	11.67a	2028.0a	1077.0a
SM	24.03	16.15c	2899.0b	1310.0b	28.15b	15.98b	2737.0b	1686.0b
F-Prob.	<.007	<.001	<.001	<.001				
Mean	23.83	13.82	2298.0	1537.0				
LSD(0.05)	4.69	1.20	282.8	206.6				

abc=Means within the same column having different superscripts are significantly (P≤0.05) different from each other, **MCL** = Maize cob length, **MRPC** = Number of rows per cob, **MGW** = Maize Grain weight (g/m^2), **MGY** = Maize grain yield (kg/ha), **SM** = Sole maize, NS = non-significant.

3.1.3. Number of Rows Per Cob

The number of rows per cob was significantly (P<0.05) influenced by plant population densities (Table 3). Also, the interaction between plant density and cassava genotypes was significantly (P<0.05) different. Apart from the 1C:1M intercropping under the NASE 14/Maize intercrop, the number of rows per cob from sole maize cropping were higher (P<0.05) than those of cobs from the NAROCASS 1/Maize and NASE 14/Maize intercrops. In general, the number of rows per cob decreased in the order SM > 1C:1M > 1C:2M indicating that as the plant population density increased, the number of rows per cob also decreased. The decrease in the number of rows per cob followed the same trend as the cob length, which shows that both growth traits are equally affected by growth conditions. The higher the plant population density, the higher the competition for growth resources that results in smaller cobs with lower numbers of rows of grain per cob (Zamir *et al*., 2011; Al-Naggar *et al.*, 2015).

3.1.4. Maize Grain Weight

Intercropping maize with cassava (NAROCASS 1 and NASE 14) significantly (P<0.05) reduced the maize grain weight (g/m^2) (Table 3). The interaction effect of plant density and cassava genotypes was non-significant (P>0.05) for maize grain weight. The reduction in grain weight is attributed to competition for growth resources, particularly sunlight. Maize is a warm season plant that requires high light intensity for optimal grain production, hence shading severely affects grain

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yield. Zamir *et al.* (2011) reported that the number of ears per plant increased with decreased plant population density. High plant population establishment creates competition for light, aeration, nutrients and consequently compelling the plants to undergo less reproductive growth.

3.1.5. Maize Grain Yield Per Hectare

Intercropping and plant population densities significantly (P<0.05) affected maize grain yield per hectare (Table 3). However, the interaction between plant density and cassava genotypes was non-significant (P>0.05). For the intercrops, maize grain yield was significantly higher at the lower plant densities of 1C:1M and sole maize cropping (SM) than for the intercrop of 1C:2M (Table 3). Thus, increasing the maize population density to 1C:2M significantly reduced the grain yields when compared with the grain yields obtained at the lower plant population density (1C:1M), as well as in the sole maize cropping.

This trend of response was also observed by Singh and Ajeigbe (2002) and Abuzar *et al*. (2011). The fact that higher grain yields were obtained when maize was intercropped with cassava at the same maize planting densities (1C:1M) as in sole maize cropping suggest that same maize populations could be used in a cassava/maize intercrop to increase the overall yields (Tollenaar and Wu, 1999). The decline in grain yield at high maize plant density of 1C:2M was attributed to competition for light, moisture and soil nutrients (Amanullah *et al*., 2006). Muoneke, *et al*, (2007) also reported that maize grain yield increased as maize plant density increased up to a point in maize/cassava intercropping. The growth and yield reduction of intercropped maize might be due to interspecific competition between the intercrop components for growth resources (light, water, nutrients, and other growth factors) and the depressive effects of cassava (Egbe and Idoko, 2012).

3.2. Cassava Response to Intercropping

3.2.1. Heights of Cassava Plants at 2 MAP, at Branching and at Harvest

There were significant differences (P<0.05) in cassava plant heights at 2 MAP, at branching and at harvest (Table 4). The interaction effect due to cassava varieties and plant population densities on cassava plant height at branching was significant (P<0.05). In the NAROCASS I / Maize intercrop, cassava heights at 2 MAP and branching were in the order SC < 1C:1M < 1C:2M indicating that as plant population density increased, the cassava plant height also increased. In fact, at the time of harvest, the height of cassava plants under intercropping system (1C:1M and 1C:2M) were similar but significantly (P<0.05) shorter than the heights of cassava plants from sole cassava cropping for both intercrops. For the case of NASE 14/Maize intercrop, the cassava heights at 2 MAP followed the same trend as in the NAROCASS 1 /Maize intercrop. At branching, cassava plants in the 1C:2M intercrops were significantly taller than those under the 1C:1M intercropping and sole cassava cropping. However, at the time of harvest, the trend was similar to that in the NAROCASS 1 /Maize intercrop (Table 4). Overall, increasing the plant population density significantly increases cassava plant height when still young (at 2 MAP and at branching). Therefore, the tallest cassava plants were in the cassava/maize intercrops of 1C:2M. This is most likely due to intensive competition for growth resources, especially light between maize and cassava plants. Shivananda (2005) reported that cassava has a wide range of growth habits which may influence the amount of solar radiation interception during growth. Adeniyan *et al*. (2014)

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also observed similar growth trends in cassava and attributed them to the competition for resources in the intercrop. The cassava plants channeled more assimilates to elongation of stems of the component crops. Quansah *et al.* (1998) also observed intense competition for space in rapidly growing crops.

Moreover, increasing the plant population increased the competition among plants for soil moisture, nutrient, light and carbon dioxide. However, in the sole cassava plants where plant population density was low, cassava plants grew as isolated units for most of their early life and interfered less with each other than at higher densities. This explains why the sole cassava plants ended up being shorter by the time of harvest.

Table 4. Effect of cassava/maize intercrop on cassava plant height at different stages of growth

	NAROCASS I / Maize intercrop			**NASE 14 / Maize intercrop**		
Treatments	CH_2	CHB	CHH	CH_2	CHB	CHH
1C:1M	21.33^b	94.20^b	184.20^a	20.63^b	97.40^a	175.50^a
1C:2M	27.63^c	149.10^c	150.20^a	25.40^c	115.10^b	149.10^a
SC	18.38^a	77.40^a	232.60^b	17.93^a	85.60^a	223.80^b
F-Prob.	**<.001**	**<.001**	**<.001**			
Mean	**21.89**	**103.1**	**185.90**			
$LSD_{(0.05)}$	**1.93**	**15.72**	**34.87**			

abc=Means within the same column having different superscripts are significantly ($P \leq 0.05$) different from each other; **CH_2 =** Cassava height at 2 MAP; **CHB =** Cassava height at branching and **CHH** = Cassava plant height at harvest, **SC** = Sole cassava.

3.2.2. Number of Cassava Roots Per Plant

Increased maize plant population density significantly ($P<0.05$) affected the number of cassava root tubers per plant (Table 5). The number of cassava root tubers per plant from sole cropping was significantly ($P<0.05$) higher than those in the intercrops (1C:1M and 1C:2M). The higher plant population (1C:2M) recorded the lowest ($P<0.05$) number of tubers per plant for both intercrops. However, the interaction effect of plant density and cassava varieties was not significant ($P>0.05$).

Table 5: Effect of cassava/maize intercrop on the yield components of cassava

	NAROCASS I / maize intercrop					**NASE 14 / maize intercrop**				
Treatment	**TN**	**RG (cm)**	**RL (cm)**	**RW (kg)**	**RY (MT/ha)**	**TN**	**RG (cm)**	**RL (cm)**	**RW (kg)**	**RY (MT/ha)**
1C:1M	20.53b	20.67a	48.27c	11.52b	28.79b	16.60b	20.93a	40.70c	10.97ab	25.42a
1C:2M	11.90a	17.75a	27.03a	9.45a	23.63a	11.00a	17.92a	24.68a	9.60a	23.00a
SC	29.20c	26.83b	38.70b	14.95c	37.38c	28.23c	40.00b	30.80b	13.93c	34.83b
F-Prob.	<.001	<.001	<.001	<.001	<.001					
Mean	19.58	24.02	35.03	11.74	29.34					
LSD(0.05)	4.44	5.45	4.98	1.57	3392					

abc=Means within the same column having different superscripts are significantly ($P \leq 0.05$) different from each other, **TN** = Number of root tubers per plant, **RG** = Cassava root tuber girth/diameter, **RL** = Cassava root tuber length, **RW =** Root tuber weight, **RY** = Cassava root tuber yield, SC = Sole cassava.

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The decrease in the number of cassava tubers per plant when cassava is intercropped with maize could be attributed to competition for the available growth resources. This means that the peak demand for growth resources of the two crop species (maize and cassava) could have coincided, hence resulting in competition that led to significant reduction in the number of cassava tubers. Marer (2007) noted that yield advantage in intercropping systems occurred where the component crops differed in their use of growth resources. Similar observations were reported earlier by IITA (2000). This result agrees with the findings of Ijoyah *et al,* (2012) who reported number of roots per plant and can be depressed by intercropping. The lowered yield of intercropped cassava might be attributed to interspecific competition between the intercrop components for growth resources (light, water, nutrients, air) and the depressive effects of shading by maize.

3.2.3. Cassava Root Girth/Diameter

Cassava root tuber girth significantly (P<0.05) decreased under intercropping compared to sole cassava cropping for both intercrops (Table 5). However, the interaction effect of plant density and cassava varieties was not significant (P>0.05). Root tuber girth at higher intercrop (1C:2M) did not differ (P>0.05) from that of the lower intercrop (1C:1M).

The reduction in cassava tuber girth when cassava was intercropped with maize could be due to competition for growth resources, especially solar radiation which could have led to lower assimilates being produced and channeled to the tubers for bulking. Cassava plants under sole cropping, had a lot of space available to them with less shading which enabled them to photosynthesize at higher levels producing a lot of assimilates that were channeled to the tubers, hence leading to the development of tubers with larger girths. Also under intercropping, more assimilates were channeled to the cassava stems which ended up being significantly taller than those of sole cassava plants. Obiero **(**2004) reported that high maize plant population in cassava/maize intercrop led to diversion of assimilates from cassava roots to the stem, and as a result there was a decrease in yield of commercially acceptable tubers. The results of this study are in conformity with those of Adjei-Nsiah (2010) who observed that total fresh tuber weight and diameter were greater (P<0.05) at lower plant populations than at high plant populations.

3.2.4. Cassava Root Length

Cassava tuber lengths were significantly (P<0.05) affected by intercropping for both cassava varieties (Table 5). Similarly, the interaction between the plant population density and the cassava varieties was significant (P<0.05). Cassava tubers from the low intercrop density (1C:1M) were longer (P<0.05) than those obtained at the higher intercrop density (1C:2M) or sole cropping. In other words, cassava tuber length significantly (P<0.05) increased when cassava and maize were intercropped in the ratio of one to one (1C:1M) for both cassava varieties, but significantly (P<0.05) decreased when the ratio of cassava to maize was changed to 1C:2M. Similar factors that were mentioned in the previous discussion could be regarded as the ones responsible for these variations (Adjei-Nsiah and Issaka, 2013). Silva *et al.* (2013) also noted that at lower planting densities, there is a surplus of production factors, notably water, nutrients and light, with a tendency for increased root tuber length. As planting densities increase, competition for those factors increases and, beyond a certain density, which varies with the trait being evaluated, root tuber length decreases.

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3.2.5. Cassava Root Fresh Weight

There were significant differences ($P<0.05$) in cassava fresh root tuber weight as influenced by plant population density (Table 5). However, the interaction effect of plant population density and cassava varieties was not significant ($P>0.05$). Fresh root tuber weight from sole cropping was higher ($P<0.05$) than that from the intercrops in NAROCASS 1/Maize intercrops. Furthermore, fresh weight of root tubers from low intercrop density (1C:1M) was greater ($P<0.05$) than that of root tubers obtained from higher intercrop density (1C:2M). Overall, root tuber weights decreased in the order SC > 1C:1M > 1C:2M indicating that as plant population density increased, root tuber weight gradually decreased. In contrast, for the NASE 14/Maize intercrops, cassava root tuber weight from sole cropping was significantly ($P<0.05$) higher than that from the intercrops (1C:1M and 1C:2M). However, root tuber weights at both the lower (1C:1M) and higher (1C:2M) plant population densities were not statistically ($P>0.05$) different.

The gradual decline in fresh root tuber weight with intercropping (SC > 1C:1M > 1C:2M) could be due to the availability of wider space per plant in the sole cropping (SC) system than in the intercrops (1C:1M and 1C:2M), that could have favored tuber development and consequently higher tuber weight. Anil-Kumar and Sasidhar (2010) reported reduced competition when cassava was planted at lower density owing to more light and nutrients being available, hence positively affecting cassava root weight.

3.2.6. Cassava Root Yield

Cassava root yield was significantly ($P<0.05$) influenced by plant population densities (Table 5). However, the interaction between the plant density and cassava varieties was not significant ($P>0.05$). Cassava root yield from sole cropping was significantly ($P<0.05$) higher than that from the intercrops for both cassava varieties. But the cassava root yield from low intercrop density (1C:1M) was higher ($P<0.05$) than that of higher intercrop density (1C:2M). Overall, cassava root yield decreased in the order SC > 1C:1M > 1C:2M indicating that as plant population density increased, the root yield gradually decreased (Table 5). Therefore, as plant population increases, competition for growth resources sets in resulting in significant reduction in tuber yield. Ayoola and Makinde (2007) observed a significant reduction in root tuber yield when the maize plant population in a cassava/maize intercrop was increased from 30,000 to 60,000 plants/ha.

3.3. Land Equivalent Ratios (Lers) of the Cassava/Maize Cropping Systems

The LERs of the different intercropping systems (1C:1M and 1C:2M) are presented in Table 6. In both cases, LERs value were greater than one indicating the yield advantage of intercropping over sole cropping of cassava and maize. According to Thobatsi (2009), this means that the intercrops were efficient in utilizing the resources, hence the yield advantage. There could also be both temporal and spatial complementarities between the component crops (Fukai and Midmore, 1993) that led to the yield advantage. These results are in agreement with those reported by Nyasasi and Kisetu (2014), Ibrahim Hamza (2008) and Ibeawuchi and Ofoh (2003).

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Table 6. Land Equivalent Ratios (Lers) of The Cassava/Maize Cropping System

	Yields (MT/ha)		**Mean yields**	**Partial LERs**		**Total LER**
Treatments	**NAROCASS 1/ Maize intercrop**	**NASE 14 / Maize intercrop**		Y*Ci / Y*Cm	Y*Mi / Y*Mm	
SM	1.31	1.69	1.50			
1C:1M	1.92	2.22	2.07			
1C:2M	1.01	1.08	1.04			
SC	37.38	34.83	36.11			
1C:1M	28.79	25.42	27.11	0.75	1.38	**2.13**
1C:2M	23.63	23.00	23.32	0.65	0.69	**1.34**

These results signify that it is advantageous to grow cassava and maize in mixtures than sole cropping, which could be due to greater efficiency of resource utilization under intercropping. The intercrop combination of one row of cassava to one row of maize (1C:1M) is better because of optimal utilization of sunlight and other growth resources with minimal competition (Kitonyo *et al*., 2013; Mariotti *et al*., 2006).

According to Ijoyah *et al*. (2013), 28.6 and 22.5% of land were saved in two separate growing seasons of intercrops, suggesting that the saved land could be used for other production activities. Muoneke *et al*. (2007) reported productivity of the intercropping system with yield advantage of 63%. Matusso *et al*. (2014) noted that one of the most important reasons for intercropping is to ensure that an increased and diverse productivity per unit area is obtained compared to sole cropping.

4. Conclusions and Recommendation

Intercropping hybrid maize with the newly released cassava varieties in the ratio of 1:1 (1C:1M) significantly increases maize grain yields than in sole maize cropping as well as when the population density of maize in the intercrop is increased to 1:2 (1C:2M). Intercropping maize with cassava varieties significantly reduces the number of cassava root tubers, tuber girth, tuber length and consequently the fresh root tuber weight. However, cassava tubers from the low intercrop density (1C:1M) were longer ($P<0.05$) than those obtained at the higher intercrop density (1C:2M). Also, cassava root yield from low intercrop density (1C:1M) was higher ($P<0.05$) than that of higher intercrop density (1C:2M).

Though there was significant reduction in cassava root yield with increased plant population density, the land equivalent ratio (LER) has shown yield advantage in the intercropping system, especially when the ratio of 1:1 is adopted. Therefore, intercropping cassava and maize in the ratio of 1:1 increases total productivity of the land.

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Competing Interests

The authors declare that there are no known competing interests.

Authors' Contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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