BIOLOGICAL WEED CONTROL EFFICIENCY AND PRODUCTIVITY OF CASSAVA-CUCUMBER INTERCROPPING SYSTEM IN UMUDIKE, SOUTHEASTERN NIGERIA

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Abstract

The concern about the control of increasing weed populations without the use of herbicides has limited farmer's ability to reduce cost of production and protect the ecosystem while in the business of farming. We investigated the biological weed control efficiency of cassava-cucumber intercropping system by and the productivity of the system using varied cucumber population densities (20,000; 30,000 and 40,000 plants/ha) and two cassava genotypes (NR 8082 and TME 419) in the southeastern part of Nigeria over two consecutive growing seasons (2012 and 2013). Result of the two experimental seasons revealed that at all record dates in both seasons cucumber plant regardless of population density, under monocultures and intercrops, significantly reduced weed population density and dry weight (g m^{-2}) relative to monocultures of each of the cassava genotypes used. The highest cucumber population density (40,000 plants ha^{-1}) under monoculture and intercrop gave the largest leaf area index and fruit yield (t ha^{-1}). No significant treatment effect was observed on cassava fresh root yield (t ha^{-1}). Assessments of system productivity by means of Land equivalent ratio (LER) and Area harvest equivalent ratio (AHER) indicated yield advantages in the 2012 and 2013 trials.

Keywords: Biological weed control, Cucumber, Cassava, Intercropping and productivity

Introduction

Weeds are important biotic constraints of agro-ecosystems that interfere in crop growth through competition and allelopathy and consequently reduce yield and quality of crops (Bastiaans *et al.*, 2008; Ali *et al.*, 2014). Evidently, an estimated worldwide crop yield loss of 43 % was reported when weeds were left uncontrolled (Oerke, 2006). Since 1940s there has been focus on the use of synthetic chemical herbicides to control the weed problem. Nowadays, this is considered objectionable due to the potential negative impacts of herbicide compounds on food security, non-target organisms, beneficial species, public health and the environment and development of herbicide resistant weeds (Fikre*et al.*, 2014). This has resulted to the advocating for the use of biological control measures as weed management option in crop production. Biological or cultural weed control methods use weeds' natural antagonists or enemies as control agents. These methods have involved the use of plants or insects for weed control. According to Bastiaans *et al.* (2008), cultural weed management is any adjustment or modification to the general management of crops or cropping systems design that contributes to the regulation of weed populations and reduces the negative impact of weeds on crop production. In this method unlike tillage, mowing, fire and chemical control methods, the control agents are single plant species specific. As stated earlier, the rationale behind biological control is not weed eradication, but rather the reduction in population below a level of economic threshold. A good biological weed control measure must have the following attributes: weakens or kills the weed, controls only the target species, does not negatively affect the growth of desirable plant species, reproduce faster than the weed, adapted to the weeds environment, and free of predators or pathogens. One good example of biological weed control measures is the use of cover cropping.

Weed suppression is one of the advantages derived from cover crops in agro-ecosystem. As a result, there is an increasing interest in the use of cover crops in agriculture (Didon *et al.,* 2014). Cover crops suppress weeds either in the form of living plants or as left over on soil surfaces or as incorporated residues (Liebman and Mhler, 2001). However, cover crops affect weed germination and establishment through nutrient release mainly nitrogen which can stimulate weed seed germination, whereas temporary immobilization of nitrogen as a result of slow decomposition rate of high C:N cover crop residue may inhibit germination of weed seeds (Liebman and Mhler, 2001). Cover crops has been reported to result in less fluctuation in soil temperature and physically reduce penetration of light, both of which have been demonstrated to inhibit germination of weed seed (Liebmanand Mhler, 2001). Cover crops may in some cases either stimulate or suppress the multiplication and activity of soil microbes which have an impact on weed seed bank (Mathiessen and Kirkegaard, 2006).

Cassava is a staple root crop in Nigeria and has diversities of uses. Principally used as human food where it produces the major source of dietary energy for well over 200 million people in Africa (Dorosh, 1988). As food, it can be processed into *gari, fufu,* flour, chips and starch (Onwueme and Sinha, 1991). The crop is a major source of cash income for the largest number of households compare with other staple thereby contributing to poverty alleviation (FMANR, 1997). Nigeria is the world's largest producer of the crop, with production rate of 54 Million metric tons (FAO, 2013). This rate does not translate to yield per unit area, as yields in farmer's fields are still low, but as a result of vast land area subjected to cassava production. The low yield being observed in farmers field can be attributed to some factors, among them is weed infestation. Consequently, increase in the production of cassava is of strategic interest to people of this region to cushion the effects of population pressure on food demand, enhance poverty reduction, achieve sustainable food and nutrition security, and to generate income (Salau, 2011). These are achievable through proper weed control measures.

Cucumber (*Cucumissativus* L.) is a widely-cultivated plant in the gourd family *Cucurbitacea*, which include Squash, and in the same genus as the Muskmelon. The plant is a creepy vine that has large leaves that form a canopy over the fruit and soil surface. They are grown for the fruits to be eaten raw or the plant to serve as cover crop. Cucumbers are wonderful as a digestive aid, and have a purifying effect on the bowl (Doijode, 2001). It can also be put in vinegar; the crop serves as a major source of vitamins for people in developing countries (Makinde *et al.,* 2009) such as Nigeria. Cucumber has been reported to be grown in an intercropping system, the mixtures include cucumber-maize and cucumber-citrus nursery (Markinde *et al.,* 2009). Intercropping of cassava with other crops is a common practice in subsistence agriculture.About 50% of cassava grown in Africa is intercropped and about 55% reported for Nigeria (Nweke *et al.,* 1996). Some of the cover crops grown in association with cassava include sweetpotato, cowpea, *telfairia*, egusi-melon and pumpkin (Njoku, 2007). Intercropping has been employed to control weed and diseases of crops. Weed competition in cassava is most harmful to the crop during the early stages of growth (3 – 4 months) after planting when it has not formed closed canopy (IITA, 1990). Complete ground cover in cassava is achieved 3 months after planting, this depends on population however. Before this stage of growth, some cover crops such as melon and beans provide early ground cover and have been utilized in intercropping systems to achieve effective weed control in cassava production (IITA, 1990). Leihner (1983) reported that when no weeding was done, 44% increase in tuber yield was obtained when cassava was intercropped with beans relative to monocropping cropping.

Planting density refers to the average number of plants per unit area (Oldenmeyer, 1980). The more closely spaced plants are, the higher the density. Planting density could impact the overall health of plants. Plantings that are too sparse (the density is too low) may be susceptible to weeds, while plantings that are too dense might result to competition for scarce resources and cause stunted growth and low yield. There is an optimum plant density for each crop. It is possible that under low plant density, although single plant production increased, yield per unit area decreased (Gardner *et al*., 1984, Ghanbari and Taheri, 2003). On the other hand, lower plants per unit area prevent maximum usage of production parameters where as high density would increase the competition and decrease crop yield. Several researches have shown that combined yields of intercropping are often higher than monocropping systems (Lithourgidis *et al*., 2006). Reasons being mainly that resources such as water, light and nutrients can be utilized more effectively under intercrop situations (Li *et al*., 2006). We hypothesized that increased population density will reduce weed biomass and enhance the productivity of cassava-cucumber intercropping system. The objectives of the study were, (i) to determine the effectiveness of cucumber (cover crop) population densities (20,000; 30,000 and 30,000 plants ha^{-1}) on weed control in cassava-cucumber intercropping system, and (ii) to access the productivity of cassava-cucumber intercropping system.

Materials and Methods

Two field experiments were conducted during the 2011/2012 and 2012/2013 cropping seasons in the research fields of the National Root Crops Research Institute, Umudike, southeastern Nigeria. Umudike is located on longitude 07^o 33' E and latitude 05^o 29' N at an altitude of 122 m in the humid tropical rainforest zone of Nigeria. The soil is derived from Coastal plain sand (Onyekwere *et. al.,* 2009). Annual rainfall ranges between 1,800 – 2,200 mm with a 65-year average of 2159.6 mm. The temperature regime is typically equatorial without substantial variation throughout the year. Annual average air temperature varies from 22^o C to 32^o C. The relative humidity varies from 51 to 87 % and sunshine hours 2.69 to 7.86 h per day (Njoku, 2007). Prior to trial establishment soil samples were collected with auger at 0 - 20 cm depth and analyzed based on the principles of soil analysis as outlined by the International Soil Reference and Information Center and Food and Agricultural Organization. (ISRIC and FAO, 2002). The sites were mechanically cleared, ploughed, harrowed and ridged (1 m apart). The field experimentation was laid out in a randomized complete block design with 11 treatments replicated 3 times with 5 m x 6 m dimension plots. Plots and replicates were separated by 1 m path ways. The treatments were combinations of three cucumber population densities (20,000; 30,000 and 40,000 plants/ha) and two cassava genotypes; TME 419 and NR 8082 characterized as erect and profuse branching cassava genotypes, respectively. Monocrops of each of the cucumber population densities and the cassava varieties were established for productivity assessments by means of land equivalent ratio (LER) and area harvest equivalent ratio (AHAR).

Cassava was planted on the crest of ridges at 1 m x 1 m to achieve a population density of 10,000 plants ha^{-1}. Two, three and four seeds of cucumber were sown per hill 30 cm away from cassava (close to base of ridges) at 1 m x 1 m to achieve plant population densities of 20,000; 30,000 and 40,000 plants ha^{-1}, respectively. Six hundred kilograms per hectare (600 kg ha^{-1}) of compound fertilizer (N:P:K 15:15:15) was applied to the crops simultaneously by drilling in two doses at 3 (300 kg ha^{-1}) and 5 (300 kg ha^{-1}) weeks after planting (WAP) . The second dose of the fertilizer was targeted at the flowering stage prior to fruit production of the cucumber plant. The plots were manually weeded once with hoe 3 WAP to eliminate early weed competition. Growth parameters recorded for cucumber at 3 and 6 WAP were leaf area (cm^2) and leaf area index. These were determined from eight sampled (tagged) plant within the four inner ridges from plots containing cucumber. Leaf area of cucumber was determined by employing the prediction equation according to Robbins and Pharr (1987) as: **Leaf area = -11.31 + 0.11 (L) + 1.14 (L^2)**. Where L = leaf length. Subsequently, the leaf area index was further computed following Eke-Okoro, (1997) procedure. The other parameters observed on cucumber was the fruit length, fruit girth and fruit yield (t ha^{-1}). This was followed by obtaining cassava height at 3 and 6 WAP (Eke-Okoro, 1997), total number of roots/plant and fresh root yield (t ha^{-1}) of cassava at the 12 months after planting. This was determined from 12 stands of cassava tagged as sample plant within the net plot. Sampled stands were taken from the four inner ridges were interaction was believed to be optimum. Weed data were taken at 4 and 12 weeks after planting from all the treatment plots in both years using a 1 m x 1 m wooden quadrant. All weed species enclosed within the thrown quadrant were taken. In each quadrant weeds were clipped at ground level, separated into weed species and counted, soils were washed off with water and dried at 80^o C for 48 hours to a constant dry weight in Carbolite electronic water extraction oven. The dried samples were weighed to determine the dry weight using an electric digital weighing balance. Productivity of the system was determined by means of Land Equivalent Ratio (LER) and Area Harvest Equivalent Ratio (AHER). The LER was calculated by adopting the formula given by Willey (1979), while AHER was calculated using the formula suggested by Balasubramanian and Sakayange (1990).

Mathematically;

$$\textbf{LER} = \frac{\textbf{Yield of component A in mixture}}{\textbf{Yield of component A in pure stand}} + \frac{\textbf{Yield of component B in mixture}}{\textbf{Yield of component B in pure stand}}$$

$$\textbf{AHER} = \sum_{i=I}^{n} \left\{ Y_{iI}/(Y_i M_n I) \right\}$$

Where

$_nI$: Total number of possible harvest of crop ***i*** that could be obtained during the full intercrop period, if crop ***i*** was monocropped (*nI* was taken as 4 in this study).

Y_{iI} : Yield of crop ***i*** in intercropping.

YiM : Yield of crop ***i*** in sole cropping.

Data for the two seasons were subjected to analyses of variance at 5% level of probability using GENSTAT statistical package. Significant treatment means were separated using least significant difference (LSD).

Results and Discussion

Soil

Particle Size Distribution

The sand fraction of the soil studied was 64.40 %, the silt content was 10.80 % while the clay content was 20.00 %. (Table 1)

Textual Classification

The textual classification of the soil was sandy clay loam. (Table 1) Generally the textual classification of this soil agrees with optimum criterion of light medium loams, sandy soils (Onyekwere *et. al.,* 2009) required for unhindered anchorage and bulking of roots and tubers, and ease of harvest.

Selected Chemical Properties

Some selected chemical properties of the soils studied are shown in Table 1

Primary Nutrients

Total nitrogen, available phosphorus and exchangeable potassium

The total nitrogen content of the soil studied was low with a value of 0.06%, far below the critical level of 0.15% required for sustainable crop production including cucumber and cassava. The low content of total N in the soil could be attributed to low organic matter of this soil, since inorganic N is accounts for only a small portion of total N in soils (Almu and Audu 2001). The low amount of total N reflects the amount of organic carbon in the soils. Variable response to applied nitrogen was thus expected in this soil for production of cassava and cucumber. The available phosphorus value was high (30.00 mg kg^{-1}) which exceeded the critical limit (8.0 mg kg^{-1}) established for crops in south eastern Nigeria, including cassava and cucumber (FPDD, 1989) and the critical level of 15 mg kg^{-1} extractable P recommended by Thomas and Peasels (1973) cited by Onyekwere *et. al.,* (2009). This result showed that the soil had the available P required for the production of both crops. The value of the exchangeable K of the soil studied was 0.09 cmol kg-^{1,} which is below the critical limit of 0.2 cmol kg^{-1} recommended for soils of southeastern Nigeria (Thomas and Peasels 1973) for the production of both crops. This result suggests that the soil will show substantial responses to applied potassium.

Soil reaction, organic carbon and exchangeable bases

The soil reaction expressed as pH (H_20) was strongly acidic with a value of 4.7. Soil acidity will not pose a problem in the production of both crops because they are acid tolerant crops. The organic carbon content was very low (0.67 %). Maintenance of a satisfactory organic matter status is essential for nitrogen availability and other nutrients taken up by unfertilized crops (Von Uxehull 1986), including cassava and cucumber. The soil was low in exchangeable Ca (1.60 cmol kg^{-1}). Exchangeable Mg in the soil was moderate with value of 0.4 cmol kg^{-1}, while exchangeable Na was low with a value of 0.12 cmol kg^{-1}.

Weed situation

Sole cassava genotypes and cucumber population densities had no significant reduction on weed population density and their corresponding dry weights (g m-^{2}) at 8 and 12 WAP (Table 2). Cucumber-cassava intercrop establishments, regardless of cassava variety and cucumber population density significantly ($P<0.01$) reduced weed population densities and dry weights relative to sole cassava establishments in both years and at all record dates (8 and 12 WAP). There was a significant reduction effect of 40,000 plants ha^{-1} sole cucumber effect of weed dry weight at 12 WAP alone in both seasons. Sole cassava recorded the highest mean values of weed population densities at 8 (82.83 and 91.84 g m-^{2}) and 12 (45.17 and 46.00 g m^{-2}) WAP in 2012 and 2013, respectively with corresponding dry weights of 30.75 and 19.83 (g m-^{2}) in 2012, and 30.93 and 21.21 (g m-^{2}) in 2013 seasons. Weed suppression is one of the services provided by cover crops to the agroecosystems. It was observed that cucumber plant suppressed the growth and development of weeds in both cropping systems by taking up spaces and utilizing available growth resources that otherwise would have been occupied and utilized by the weeds. The live cucumber plants prevented the emergence, growth, development and seed production of weeds through competition for essential resources such as water, nutrients and light. This finding conformed with the reports of Liebman and Mohler (2001); Bastiaans *et al.* (2007); Teasdale *et al*. (2007); Kruidhof *et al.* (2008); Ohnoc *et al.* (2000) and Kruidhof *et al*. (2009) on the use of various species of cover crops for ecological/cultural weed management. Furthermore, Brennan and Smith (2009) stated that the degree of reduction in growth and development attributed to the living cover crops is highly correlated with the extent of reduction in weed seed production. A mechanism that provides continuous and adequate weed suppression throughout the life cycle of weeds is preferred in agroecosystems (Firkre *et al.*, 2004), that is what the findings of this study has demonstrated. It was observed that cucumber generally influenced weed densities at multistage in the life cycle of weed. These include preventing or reducing production of propagules, reducing seedling establishment which is a function of germination, emergence and minimizing successful establishment of individual weed through by adversely influencing their competitive abilities.

Growth, yield components and yield of cucumber

Number of leaves, fruit length and fruit girth were not influenced by cassava-cucumber intercrop mixtures both years and across sampling dates (Table 3). However, leaf area index (LAI) at 6 WAP and fruit yield (t ha^{-1}) were significantly ($P<0.01$) influenced by cucumber population densities in both years. Table 3 showed that the highest cucumber population density (40,000 plants ha^{-1}), whether sole or intercropped, had the highest LAI and fruit yield. The order of significance for fruit yield and LAI are; 40,000 > 30,000 > 20,000 and 40,000> 30,000 = 20,000 plants ha^{-1}cucumber, respectively for both parameters (Table 3). Cucumber is a creeping cover crop that completes life cycle within 3 months while cassava takes about 12 months to attain maturity. Both crops have high nutrient demands at different stages which makes them very good companion crops. In 2012 and 2013, sole cucumber (40,000 plants ha^{-1}) gave the highest LAI mean values (1.83 and 1.86 at 6 WAP, respectively). In 2012 and 2013, NR 8082 + 40,000 plants h^{-1} cucumber (10.38 t ha^{-1}) and TME 419 x 40,000 plants ha^{-1} cucumber (11.92 t ha^{-1}) produced the highest fruit yields. William (2012) and Baron *et al.* (2006) reported that one of the ways of increasing leaf area index and yield of crops is by increasing plant population density. Increased leaf area index enhances photosynthetic capacity and assimilate production of crops (Seyyed *et al.*, 2012) which subsequently increases crop yield so long as the optimum population density at which competition effects becomes apparent is not exceeded. Lizaso *et al.* (2003) reported that the average absorbed photosynthetic active radiation (PAR) by leaf area at reproductive stage was the determinant factor of corn yield while the decrease in yield had a high correlation with the decrease in corn leaf area.

Cassava growth, yield components and yield

Cassava-cucumber intercrop had no influence on the cassava yield (tha^{-1}) and height at 3 and 6 WAP (Table 4). However, there was a cassava varietal effect on mean number of roots per plant in 2012 and 2013 among the cassava genotypes in monocropping (Table 4). In 2012 and 2013 seasons NR 8082 consistently produced higher mean number of roots per plant relative to TME 419. This was attributed to varietal differences rather than growing conditions. Intercropping, compared to sole cropping generally reduced root yields both cassava genotypes by 10.94 % and 10.59 % in 2012 and 2013 seasons, respectively. Njoku (2007) reported reduced marketable and unmarketable root yields of cassava by 22% and 35%, respectively in cassava-cowpea intercropping system. Cowpea-cassava intercropping trials in South America (CIAT, 1993) revealed that cowpea depressed cassava root yields by over 30 %. Cowpea and cucumber share similar characteristics in the sense that both are short season cover crops though the former (cowpea) is a legume. The wide maturity gap between cucumber (about 90 days) and cassava (about 360 days) and the slow initial growth of cassava enhanced the compatibility of both as intercrops.

Productivity of the system: Land Equivalent Ratio (LER) and Area Harvest Equivalent Ratio (AHER)

Most of the intercrop treatments of cassava and cucumber regardless of cassava genotype and cucumber population density had high LER and AHER values indicating yield advantages. The highest LER and AHER values were recorded against NR 8082 + 30,000 plants ha^{-1} cucumber in both years (Table 5). Higher LER values have been reported by many researchers when cassava was grown in association with short duration crops such as cassava-cowpea intercrop (Njoku and Muoneke, 2008). Land equivalent ratio (LER) of 1.48 to 1.56 by Mason *et al.* (1986), 1.50 to 1.73 by Mba and Ezumah (1985) and similarly an LER of 1.36 to 1.84 (Ezumah, 1988), 1.16 to 1.69 (Osiru and Hahn, 1988) in cassava-maize intercrops which all corroborate the findings from this study. The AHER concept which combines the area and time factor in a practical sense for qualifying intercrop yield advantages particularly in multi-season association has been shown to be a better and more practical measure of intercrop productivity assessment (Balasurbramanian and Sekeyange, 1990). An AHER of 1.14 in cassava + cowpea combination reported by Balasurbramanian and Sekeyange (1990) is in agreement with the AHER values (1.17 and 1.20) recorded against NR 8080 + 30,000 plants/ha cucumber in both seasons of this study.

Conclusion

It was established from our study that cucumber plant population densities (20,000; 30,000 and 40,000 plants/ha) is very effective for biological weed management. The crop can be intercropped with either of the cassava genotypes (TME 419 and NR 8082) used in our study at a population density as high as 40,000 plants ha^{-1}. However, for higher productivity, cucumber should be intercropped with cassava at 30,000 plants ha^{-1}.

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Table 1: Mean particle size distribution and chemical properties of the experimental site 2011/2012 and 2012/2013 trial seasons.

Parameter	value
pH	4.70
Total N	0.06
Avail. P (mg kg-1)	30.00
Organic M (%)	0.67
Exch. Ca (cmol kg-1)	1.60
Exch. Mg (cmol kg-1)	0.40
Exch. K (cmol kg-1)	0.09
Exch. Na (cmol kg-1)	0.12
Sand (%)	68.40
Silt	10.80
Clay	20.80
Textural classification	Sandy clay loam

Table 2: Effect of Cassava varieties and Cucumber population densities on weed density and weed dry weight/m^2 in cassava/cucumber intercropping system in 2012 and 2013

	Weed density/m^2 (WAP)				Weed dry matter (g/m^2) WAP			
	2012		2013		2012		2013	
Treatment	8	12	8	12	8	12	8	12
Sole TME 419	81.66	46.00	93.34	47.34	31.31	19.28	30.48	20.52
Sole NR 8082	84.00	44.34	90.34	44.66	30.20	20.38	31.38	21.90
Mean	**82.83**	**45.17**	**91.84**	**46.00**	**30.75**	**19.83**	**30.93**	**21.21**
Sole Cucumber @ 20,000 plants/ha.	62.00	27.66	61.34	22.00	13.49	11.06	13.54	10.94
Sole Cucumber @ 30,000 plants/ha.	45.00	19.60	47.00	16.34	10.48	9.56	11.12	9.31
Sole Cucumber @ 40,000 plants/ha.	34.66	16.00	35.34	12.66	8.74	7.12	8.92	6.12
Mean	**47.22**	**21.08**	**47.21**	**17.00**	**10.89**	**9.24**	**11.19**	**8.79**
TME 419 x Cucumber @ 20,000 plants/ha.	24.00	11.34	26.66	14.00	6.08	5.00	7.32	5.62
TME 419 x Cucumber @ 26,666 plants/ha.	22.66	9.34	23.20	10.34	5.14	4.00	5.56	5.14
TME 419 x Cucumber @ 40,000 plants/ha.	9.00	4.84	10.34	6.66	3.60	2.40	3.02	3.04
Mean	**18.55**	**8.50**	**20.06**	**10.00**	**4.94**	**3.8**	**5.3**	**4.6**
NR 8082 x Cucumber @ 20,000 plants/ha.	20.34	11.00	28.34	12.34	7.80	4.34	6.78	4.56
NR 8082 x Cucumber @ 26,666 plants/ha.	15.52	9.66	26.00	8.71	5.22	3.12	5.42	3.50
NR 8082 x Cucumber @ 40,000 plants/ha.	7.66	4.66	13.34	5.00	3.02	2.80	4.04	1.84
Mean	**14.50**	**8.44**	**22.56**	**8.68**	**5.34**	**3.42**	**5.41**	**3.63**
$LSD_{(0.05)}$	30.10	15.48	31.40	9.72	10.32	9.82	12.20	10.14

NS = Not significant at P>0.05, LSD = Least Significant Difference

Table 3: Effect of Cassava varieties and Cucumber population densities on some growth, yield and yield components of cucumber in cassava/cucumber intercropping system in 2012 and 2013

Treatment	No. of leaves (6 WAP)		Leaf area index (6WAP)		Fruit length (cm)		Fruit girth (cm)		Fruit yield (t/ha)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Cucumber @ 20,000 plants/ha.	35.41	36.01	1.42	1.40	12.64	12.86	14.01	14.35	6.76	6.42
Cucumber @ 30,000 plants/ha.	33.82	35.23	1.60	1.71	12.84	13.15	13.82	14.13	8.39	9.06
Cucumber @ 40,000 plants/ha.	34.11	34.28	1.82	1.83	11.07	11.77	13.16	13.67	10.06	11.72
Mean	**34.44**	**35.17**	**1.61**	**1.64**	**12.18**	**12.59**	**13.66**	**14.05**	**8.40**	**9.06**
TME 419 x Cucumber @ 20,000 plants/ha.	35.12	35.08	1.34	1.41	12.62	12.74	13.32	13.93	6.42	7.72
TME 419 x Cucumber @ 30,000 plants/ha.	34.76	35.29	1.58	1.68	11.81	13.34	13.87	14.43	8.39	9.06
TME 419 x Cucumber @ 40,000 plants/ha.	33.01	34.44	1.76	1.82	12.43	13.57	15.01	14.09	10.26	11.92
Mean	**34.29**	**34.93**	**1.56**	**1.63**	**12.28**	**13.21**	**14.06**	**14.15**	**8.69**	**9.56**
NR 8082 x Cucumber @ 20,000 plants/ha.	35.23	34.81	1.40	1.45	11.89	12.63	13.11	13.35	6.90	7.45
NR 8082 x Cucumber @ 30,000 plants/ha.	34.43	35.08	1.62	1.70	12.92	13.46	14.42	14.43	9.02	9.12
NR 8082 x Cucumber @ 40,000 plants/ha.	34.11	33.11	1.79	1.86	12.08	12.03	14.84	15.52	10.38	11.04
Mean	**34.59**	**34.33**	**1.60**	**1.67**	**12.29**	**12.70**	**14.12**	**14.43**	**8.76**	**9.20**
$LSD_{(0.05)}$	NS	NS	0.38	0.36	NS	NS	NS	NS	1.13	1.14

NS = Not significant at P>0.05, LSD = Least Significant Difference

Table 4: Effect of Cassava varieties and Cucumber population densities on growth, yield and yield component of cassava in cassava/cucumber intercropping system in 2012 and 2013

Treatment	Plant height (cm)				Total no roots/plant		Root yield (t/ha)	
	2012		2013		2012	2013	2012	2013
	3WAP	6 WAP	3WAP	6 WAP				
TME 419	18.33	35.23	18.41	32.11	4.10	4.00	40.31	42.81
NR 8082	20.67	36.97	18.12	35.13	6.78	6.52	39.94	40.24
Mean	19.5	36.10	18.26	33.62	5.44	5.26	40.12	41.52
TME 419 x Cucumber @ 20,000 plants/ha	18.75	36.19	18.14	38.14	5.45	4.48	33.21	35.62
TME 419 x Cucumber @ 30,000 plants/ha	19.83	38.76	18.11	34.12	4.17	5.15	33.61	34.41
TME 419 x Cucumber @ 40,000 plants/ha	19.92	38.88	19.01	34.11	4.15	5.01	35.76	37.11
Mean	19.5	37.94	18.42	35.45	4.59	4.88	34.19	35.71
NR 8082 x Cucumber @ 20,000 plants/ha	19.92	38.88	19.03	37.34	6.15	6.08	36.52	37.12
NR 8082 x Cucumber @ 30,000 plants/ha	18.50	36.83	19.18	36.33	5.15	5.13	39.52	41.41
NR 8082 x Cucumber @ 40,000 plants/ha	19.58	38.70	20.11	35.19	5.82	6.00	35.82	37.07
Mean	19.33	38.13	19.44	36.28	5.70	5.73	37.28	38.53
LSD	NS	NS	NS	NS	2.35	2.08	NS	NS

NS = Not significant at P>0.05, LSD = Least Significant Difference

Table 5: Effect of Cassava varieties and Cucumber population densities on the productivity of cassava/cucumber intercropping system in 2012 and 2013

	Land equivalent ratio (LER)		Area harvest equivalent ratio (AHER)	
Treatment	2012	2013	2012	2013
TME 419 x Cucumber @ 20,000 plants/ha.	1.69	1.67	1.00	1.01
TME 419 x Cucumber @ 30,000 plants/ha.	1.79	1.75	1.02	1.00
TME 419 x Cucumber @ 40,000 plants/ha.	1.55	1.54	1.00	1.00
NR 8082 x Cucumber @ 20,000 plants/ha.	1.71	1.73	1.06	1.06
NR 8082 x Cucumber @ 30,000 plants/ha.	1.98	2.01	1.17	1.20
NR 8082 x Cucumber @ 40,000 plants/ha.	1.64	1.68	1.03	1.05