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Research Article
Sequential Cropping Effects of Vegetable Cowpea on Cassava in Cassava-cowpea Intercrop, Umudike, Southeast Nigeria

Mbah, Emmanuel Ukaobasi

Department of Agronomy, Michael Okpara University of Agriculture, Umudike, Nigeria

Abstract

Objective: A field crop experiment was conducted in 2015 and 2016 cropping seasons with the aim of quantifying the effect of sequential planting of vegetable cowpea on crop growth, yield and productivity of component crops in cassava and cowpea intercrop as well as to assess the nutrient status of the soil at harvest. **Materials and Methods:** The treatments comprised of four cassava cultivars intercropped with vegetable cowpea grown using sequential method in the system (NR 8082//cowpea, TMS 30572//cowpea, TME 419//cowpea, TMS 98/0505//cowpea) and their respective mono-crops. The experiment was laid out in a randomized complete block design with three replications at Umudike (05°29′N, 07°33′E, 122 m.a.s.l.), Southeastern Nigeria. In the systems, intercropping exhibited lower values in all the plant variables evaluated compared with their respective mono-cropped component crops in the plots. **Results:** The findings showed that there was a higher degree of complementarity between cassava and cowpea and also increased nutrient status of the soil in cowpea sown plots at harvest. The productivity indices indicated that NR 8082//cowpea intercrop exhibited highest total land equivalent ratio (LER), land equivalent coefficient and %-land saved compared to other mixes. However, financially TMS 98/0505//cowpea intercrop was more productive with the highest total gross monetary return, net return (NR) and benefit cost ratio (BCR) relative to the other treatments in the systems. The sequence of BCR in the mixes was in the order: TMS 98/0505//cowpea>NR 8082//cowpea>TMS 30572//cowpea>TME 419//cowpea. **Conclusion:** The regression relationships between BCR and total crop yield and between LER and %-land saved were linear and positive. Therefore, sequential cropping of vegetable cowpea in cassava intercrop exhibited strong and positive impact on the productivity of the system.

Key words: Sequential cropping, *Manihot esculenta*, *Vigna unguiculata*, productivity, soil nutrient status

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Corresponding Author: Mbah, Emmanuel Ukaobasi, Department of Agronomy, College of Crop and Soil Sciences, Michael Okpara University of Agriculture, Umudike, P.M.B. 40444, Umuahia, Abia State, Nigeria Tel: +234 803 460 8421

Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Intercropping, which is a multiple type of cropping system enables component crops to interact and relate with available growth resources (solar radiation, soil nutrients, moisture, temperature and even space) following agronomic principles[1-5]. Hence, under the system, there is more efficient use of growth resources by component crops either from different rooting levels in the soil, aerial environment, difference in time of growth demand, or different nutrient requirements such as legumes that may use more atmospheric N_2 compared to non-legumes that may use reduced soil nitrogen[6-8]. Also, it encourages a more efficient use and utilization of resources such as moisture, solar radiation and nutrients[9,10] as well as reduces the negative effect of weeds, insect pests and diseases[11-15]. A wide range of previous studies on intercropping by Okpara *et al.*[7], Ennin and Clegg[16], Calvino and Monzon[17], Bedoussac and Justes[18], Hinsinger *et al.*[19], as well as Neugschwandtner and Kaul[20] indicated that the system positively impacts on improving not only crop yield and yield components but also yield quality of the component crops in the associated system by direct contact or complementarity or facilitation of growth resources within the cropping circuit for the overall benefits of the companion crops.

Cowpea is not only an important food and forage crop but a valuable commodity crop for farmers in the humid agro-ecological zone of Nigeria[21-24]. According to Udoh and Ndaeyo[4], Ishyaku and Singh[25] as well as Santalla *et al.*[26], cowpea can be eaten in the form of dry seeds, green pods, green seeds and tender green leaves and it can also be fed to animals in the form of fodder and feed. Furthermore, the crop has high agronomic value in sustainable farming systems owning to its ability to fix atmospheric nitrogen in the soil, hence, plays a vital role in soil amendments[21,27,28].

Cassava is one of the most dominant food security crops in West Africa, especially for some 500 million people residing in the Sub-Sahara region but currently assuming a new status as a major source of animal feed and industrial raw material for bio-energy[21,29]. Studies have shown that sustainable cassava production depend on the use of genotypes adapted to the environment[30-32], the efficacy of the field crop management and its complementarity with other component crops in the mixes, especially legumes[33-35]. Cassava and vegetable cowpea mixes improve diets, soil fertility and enhance overall crop productivity. However, there is dearth information on intercropping cassava genotypes with contrasting morpho-types with prostrate cowpea (*Vigna unguiculata* Walp. ssp. *Sesquipedalis*) using sequential planting technique during the long gestation period of the cassava component crop. Therefore, this study was initiated purposely to assess the crop yield performance, productivity and nutritional status of the soil in cassava-vegetable cowpea intercrop as affected by sequential planting of cowpea in the mixes as a soil fertility booster and live mulch.

MATERIALS AND METHODS

Site characteristics: Four cassava cultivars - vegetable cowpea and their respective sole crops were grown at National Root Crops Research Institute, Umudike (longitude 05°29′N, Latitude 07°33′ E, elevation 122 m.a.s.l.), Nigeria in 2015/2016 cropping season. Total annual rainfall and rain-days during the period of investigation was 2,069 mm and 123 days, respectively (Fig. 1a, b). The rainfall pattern is bimodal (April-July) and (September-November), while the minimum and maximum temperatures of the area were 23.2 and 31.7°C, respectively (Fig. 1). The soil of the experimental site belongs to the order ultisol and classified as Typic (Paleustalt)[36]. It had low humus content with top sandy texture. It was acidic.

Land preparation, treatment application and experimental design: The experimental field was under fallow for 2 years with vegetation cover which had *Panicum maximum*, *Aspilia africana*, *Imperata cylindrica*, *Calopogonium mucunoid*, *Cyperus rotundus*, *Mimosa invisa Chromolaena odorata* and *Ipomoea involucrate*. The experimental plots were slashed, ploughed, harrowed and one metre ridges made. The field layout was marked using tape, pegs and ropes. The plots measured 5 m in length and 5 m in width with one and two metre spacing between plots and blocks, respectively. The experiment was laid down in a randomized complete block design with three replicates.

Four cassava cultivars were used in the study. The two high cyanide (NR 8082 and TMS 30572) characterized by high and low branching orders, respectively and two low cyanide (TME 419 and TMS 0505) characterized by erect and high branching orders, respectively, were sourced from the Cassava programme, National Root Crops Research Institute, Umudike, Nigeria while a land race prostrate vegetable cowpea was purchased from a local farmer at Enugu, Nigeria. The nine treatments studied were: (1) monocrop NR 8082 (2) monocrop TMS 30572 (3) monocrop TME 419 (4) monocrop TMS 0505 (5) monocrop vegetable cowpea and their respective intercrops (6) NR 8082//vegetable cowpea (7) TMS 30572//vegetable cowpea (8) TME 419//vegetable cowpea (9) TMS 0505//vegetable cowpea. The sole crop plots of cassava and vegetable cowpea were established as controls and for

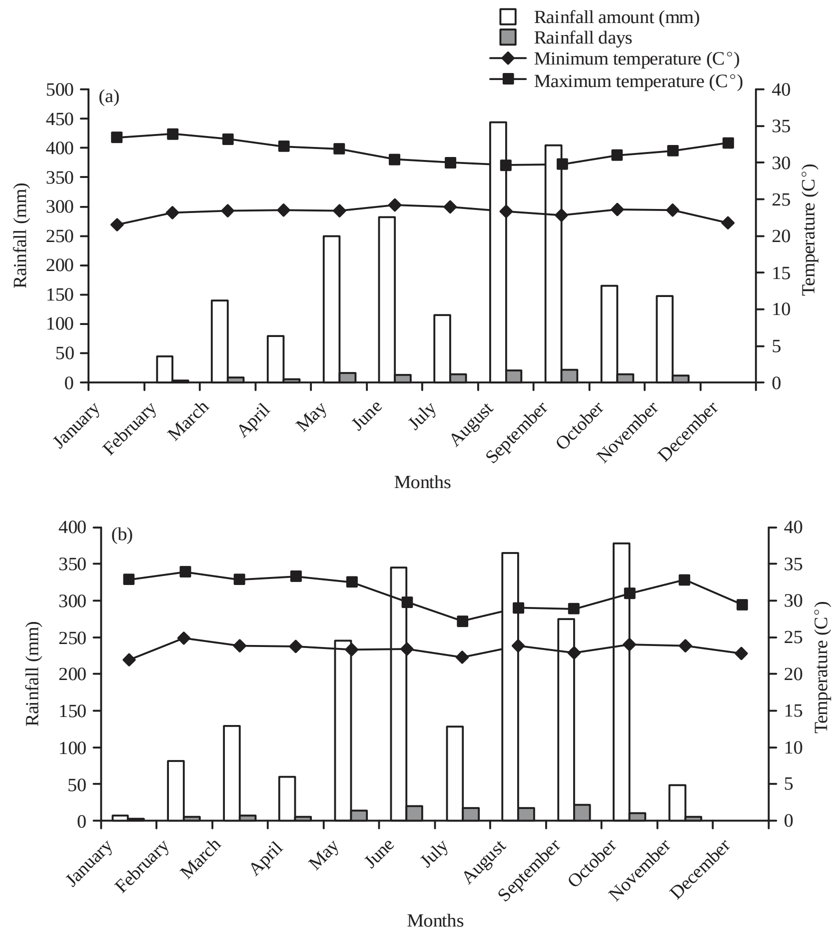

Fig. 1(a-b): Mean monthly rainfall amount and rainfall days, as well as minimum and maximum air temperatures of the experimental site in 2014 and 2015 cropping seasons
Source: Meteorological unit, National Root Crops Research, Institute, Umudike, Nigeria

the computation of land equivalent ratio and other productivity indices required in the system. To reduce variability among cassava planting materials, 20 cm cuttings (with 4-6 nodes) were cut out from 80-100 cm of 12 months old stems.

The cuttings were planted slanting (45°) on the crest of the ridges, one meter apart. Three seeds of vegetable cowpea were planted at a spacing of 0.50×1.0 m per hole in May (early cropping season). Supplying missing stands of cassava and thinning of vegetable cowpea seedlings to two per stand to give a plant population of 10,000 and 40,000 plants ha^{-1}, respectively were done 14 days after emergence. In mono-cropped cowpea, three seeds that were later thinned to two were planted $hole^{-1}$ at 0.25×1.0 m to give a plant population of 80,000 plants ha^{-1}. The first vegetable cowpea was completely harvested four months after planting from all the corresponding cowpea plots and the second cowpea planting (sequential) was introduced immediately after the first crop was removed from the plots.

Plots comprised five rows of cassava to give 25 plants $plot^{-1}$ and vegetable cowpea had ten rows to give 100 plants $plot^{-1}$ in both sole and intercrop. The experimental area was hoe-weeded and the ridges remoulded at three weeks after planting to enable the crops establish properly and allow the quick growing vegetable cowpea to gain vigour and ramify the growing surface area.

Soil sampling and laboratory analysis: The soil samples from the experimental area were collected with the aid of auger from the top 25 cm of the soil from three blocks to have a composite sample, which was bulked and air-dried at room temperature of between 25 and 27°C for 14 days and crushed to pass through a 2 mm sieve. A sub-sample of the soil was collected and subjected to physico-chemical analysis

Table 1: Physico-chemical properties of the top soil (0-25 cm) of the experimental site, Umudike, Nigeria in 2015 cropping season

Physical properties	Values	Methods
Sand (g kg^{-1})	764	Hydrometer method[37]
Silt (g kg^{-1})	108	
Clay (g kg^{-1})	128	
Textural class		Sandy loam characterized as ultisol (USDA Classification)
Chemical properties		
pH (1:2.50, Soil:Water ratio)	4.80	Determined using a suspension of soil and distilled water. After stirring for 30 min, the pH value was read using an electronic glass electrode pH meter, Jenway model 3510[38]
Total nitrogen (%)	0.084	Semi-micro kjeldahl digestion method using sulphuric acid and copper sulphate and sodium sulphate catalyst mixture[39]
Organic carbon (%)	1.04	Improved chromic acid digestion and spectrophotometric method[40]
Organic matter (%)	1.79	Wet oxidation method through chromic acid digestion[41]. Percentage organic matter was derived by multiplying percentage organic carbon by Broadbent's factor of 1.72
Available phosphorus (mg kg^{-1})	17.50	Molybdenum blue colorimetry method[42]
Exchangeable bases		
Na^{+} (cmol (+) kg^{-1})	0.148	Ammonium acetate extraction method and read on flame photometer using FP 8800 model, with acetylene of
K^{2+} (cmol (+) kg^{-1})	0.117	propane burner[42]
Ca^{2+} (cmol (+) kg^{-1})	2.80	Ammonium acetate extraction method and determined using ethylenediaminetetraacetic acid (EDTA)
Mg^{2+} (cmol (+) kg^{-1})	1.60	titration method with the model 8089-A2[42]
EA (cmol (+) kg^{-1})	0.71	Ammonium nitrate (NH_4NO_3 (1M) was used as an extractant
ECEC (cmol (+) kg^{-1})	5.375	Soil exchangeable acidity (H+) was determined by titration of normal KCl-extracted acidity against 0.05 N sodium hydroxide. Effective cation exchange capacity (ECEC) was obtained by a summation of the exchangeable cations (Na, K, Mg, Ca) and exchangeable acidity
Base saturation (%)	90.56	Base saturation was obtained by calculation as the percentage of the CEC occupied by the basic cations Na^{+}, K^{2+}, Mg^{2+}, Ca^{2+} and (%) BS = $[(Na^{+}+K^{2+}+Mg^{2+}+Ca^{2+})/CEC]\times 100$

Source: Soil science laboratory, National root crops research institute, Umudike, Nigeria

using standard laboratory methods prior to experimentation (Table 1). In a similar manner, auger soil samples were collected from three observational points at a depth of 0-25 cm in each of the 36 experimental plots immediately after total harvest of the component crops and used to determine some chemical properties of the soil. The soil samples were air-dried, crushed and sieved with a 2 mm sieve before they were subjected to laboratory analysis.

Growth parameters measured were plant height, number of leaves plant^{-1}, number of branches plant^{-1}, cassava canopy diameter, plant biomass and yield as well as some yield related parameters. At 12 weeks after planting (WAP), six plants each from the component crops located in the inner rows of the plots were selected, tagged and used for biological measurements.

The plant height (cassava) or vine length (vegetable cowpea) and canopy diameter of cassava were measured with the aid of a meter rule. The plant height was measured from the base of the plant to terminal bud while canopy diameter was determined by placing the metre rule across the diameter of the canopy foliage. The number of leaves plant^{-1} was determined by visual counting of the number of leaves for each component crop. Plant bio-mass of the component crops was determined by recording the weight of whole plant shoots while root shoot ratio and harvest index were determined by calculation. At 12 months after planting, cassava yield parameters collected were root diameter, root length, weight of marketable roots plant^{-1} and fresh root yield (Mt ha^{-1}).

At 16 weeks after planting, yield and yield components of vegetable cowpea recorded include number of pods plant^{-1}, weight of fresh pods plant^{-1} and fresh pod yield (Mt ha^{-1}). The Pod weight plant^{-1} was weighed with triple bean balance (Haus Model) while cowpea crop yields were obtained by harvesting the crops from the net area (4 m^{-2}) of each plot and extrapolated to hectare. Vegetable cowpea was harvested when pods were fully filled and matured but still green. The green pod yields in each plot were weighted and recorded.

The biological and economic productivity of the systems were determined by comparing productivity of a given area of intercropping with that of monocrops using functions for land equivalent ratio (LER) (the sum of the ratios of the yields of the intercrops to those of the monocrops) according to Mead and Willey[43]. The land equivalent coefficient (LEC) of the intercrops was determined as the products of partial LERs from the components crops[44] while percentage land saved was determined using the formulae:

According to Willey[45].

$$\text{Land saved (\%)} = 100 - \frac{1}{\text{LER}} \times 100$$

The gross monetary return (\$ ha^{-1}) was obtained by multiplying the yield of the component crops with the current market price of the farm produce in the locality at time of harvest. The total cost of production (\$ ha^{-1}), was calculated considering all operational expenses, beginning with land acquisition, machinery land preparation, purchasing of farm in-puts such as seeds, cuttings and fertilizer, planting, field maintenance to harvesting, initial processing and marketing of farm produce. The net return (\$ ha^{-1}) was obtained by subtracting the total cost of production from the gross monetary return recorded from the systems and the benefit-cost ratio (BCR), the ratio of net return to total cost of production, was calculated.

Statistical analysis: The data were subjected to analysis of variance (ANOVA) separately for each crop using the General Linear Model of SAS software for randomized complete block design (RCBD)[46]. The cassava crop was subjected to two-way factorial analysis while the vegetable cowpea was subjected to one-way analysis of variance. Fixed effects were cropping systems and cassava cultivars while replications (blocks) were random effects. The statistical significance of a given factor at different levels of the other factor (simple main effect) was obtained using the least square means (LSMEANS). Mean separation was performed using Fisher's least significant difference (F-LSD) at $p<0.05$ according to Obi[47]. The Pearson's multiple correlation analyses were carried out on agronomic characters of cassava and vegetable cowpea using PROC CORR of SAS[46].

RESULTS

Two-way analysis of variance indicated that cropping system significantly ($p<0.05$) affected plant height and root diameter of cassava contrary to the other variables (Table 2) while significant variation among cassava genotypes was recorded in number of leaves plant^{-1}, plant biomass, harvest index, weight of marketable roots plant^{-1} and fresh root yield of cassava. The interaction between cropping system and genotype indicated significant variation in number of leaves plant^{-1}, root/shoot ratio, weight of marketable roots plant^{-1} and fresh root yield of cassava.

The factor interaction between cropping system and genotype (Table 3) indicated that TMS 98/0505 cassava genotype in the mixes had the highest number of leaves plant^{-1}, root/shoot ratio, weight of marketable roots plant^{-1} and fresh root yield (Mt ha^{-1}) compared with other genotypes in both mono- and intercrop. In contrast, mono-cropped TME 419 cassava genotype had the smallest weight of marketable roots plant^{-1} and fresh root yield in both cropping systems.

One-way analysis of variance of cropping system and treatment (Table 4) showed that cropping system and treatment effect had no significant ($p>0.05$) effect on vine length and number of branches plant^{-1}. However, in contrast to treatment, cropping system also had no effect on number of leaves plant^{-1}. Cropping system and treatment exhibited significant difference to the other assessed variables (plant biomass, number of pods plant^{-1}, weight of fresh pods plant^{-1} and fresh pod yield hectare^{-1}) of vegetable cowpea. Among the systems, intercropping exhibited lower values in plant biomass, number of pods plant^{-1}, weight of fresh pods plant^{-1} and fresh pod yield by 55, 23, 46 and 46%, respectively relative to the mono-cropped cowpea. Intercropped TME 419//cowpea had the highest number of leaves plant^{-1} and number of pods plant^{-1} contrary to the other cassava//cowpea mixes. The fresh pod plant^{-1} and fresh pod yield (Mt ha^{-1}) obtained from mono-cropped cowpea weighted more relative to the mixes while cassava TMS 98/0505//cowpea intercrop gave the highest amount of valued fresh pod yield among the intercrops.

Correlation analysis (Table 5) on the cassava component indicated that weight of marketable roots plant^{-1} and root:shoot ratio showed positive and highly significant

Table 2: Two-way analysis of variance for cropping system, cassava cultivar effects and their interactions on growth, root yield and yield components of cassava in mono- and intercrop

	12 WAP						Roots		
Sources	Plant height (cm)	Number leaves plant^{-1}	Plant biomass (g)	Root/shoot ratio	Harvest index	Weight marketable roots plant^{-1}	Length (cm)	Diameter (cm)	Yield (Mt ha^{-1})
Cropping system (C)	*	ns	ns	*	ns	ns	ns	*	ns
Mean square	11180.0	9.0	31.97	1.1267	20.91	3.40	0.072	141.77	87.21
Genotype (G)	**	*	*	ns	**	*	ns	ns	*
Mean square	12373.0	21584.0	76.08	0.2897	507.24	70.84	2.952	11.18	274.95
Interaction C×G	ns	*	ns	*	ns	*	ns	ns	*
Mean square	104.0	9656.0	27.30	0.8319	25.70	45.28	1.445	23.17	63.42

ns,*, **: Not significant, significant at $p<0.05$ or $p<0.01$, respectively. SED: Standard error of difference between means. Analysis of variance

Table 3: Effect of cropping system and genotype interaction on some growth and root yield parameters of cassava[a] in mono- and intercrop

Cropping system	Genotype	Number leaves plant^{-1}	Root/shoot ratio	Weight marketable roots (kg plant^{-1})	Fresh root yield (Mt ha^{-1})
Mono-crop	NR 8082	96.0	1.17	8.87	19.10
Mono-crop	TMS 30572	289.0	1.32	7.53	18.60
Mono-crop	TME 419	133.0	1.11	6.31	12.10
Mono-crop	TMS 0505	286.0	1.60	12.33	33.60
Intercrop	NR 8082	187.0	1.13	12.21	17.50
Intercrop	TMS 30572	118.0	0.84	11.08	18.10
Intercrop	TME 419	106.0	0.73	10.86	08.90
Intercrop	TMS 98/0505	189.0	1.32	19.69	20.50
SED		40.9	0.2290	2.719	4.12
$LSD_{(0.05)}$		87.8	0.4912	5.832	8.83

ns, *, **: Not significant, significant at p<0.05 or p<0.01, respectively. SED: Standard error of difference between means. Two-way ANOVA, [a]Data in interaction with least squares means and means separation with least significant difference (LSD)

Table 4: One-way analysis of variance for cropping system and treatment effects on growth, fresh pod yield and yield components of cowpea in mono- and intercrop

	12 WAP						
Cropping systems	Vine length (cm)	Number branches plant^{-1}	Number leaves plant^{-1}	Plant biomass (kg)	Number pods plant^{-1}	Weight fresh pods plant^{-1} (g)	Fresh pod yield (Mt ha^{-1})
Mono-crop	733	64.8	629.0	2387.0^{a}	231.30^{a}	406.0^{a}	16.24^{a}
Intercrop	791	61.1	718.0	1072.0^{b}	177.90^{b}	219.0^{b}	8.77^{b}
SED	69.4	3.72	830.1	297.1	140.19	29.80	1.194
ANOVA GLM							
Treatment significance	ns	ns	ns	*	*	*	*
Mean square	5119.0	26.89	15811.0	3456263.0	5706.50	69751.0	111.602
Treatment							
Monocropped cowpea	733	64.3	628.67^{b}	2.387^{a}	231.33^{ab}	406.00	16.24^{a}
NR 8082//cowpea	735	61.7	716.67^{ab}	1040.0^{b}	930.00^{c}	236.67	9.47^{b}
TMS 30572//cowpea	833	59.7	656.00^{b}	1153.33^{b}	116.33^{bc}	163.33	6.53^{b}
TME 419//cowpea	811	69.3	887.33^{a}	1161.67^{b}	290.33^{a}	206.67	8.27^{b}
TMS 98/0505//cowpea	785	53.7	610.33^{b}	933.33^{b}	212.00^{abc}	270.33	10.81^{b}
SED	94.70	8.02	940.20	338.90	520.40	490.00	1.959
ANOVA GLM							
Treatment significance	ns	ns	*	**	*	ns	**
Mean square	5924.57	100.40	37827.0	1063058.0	20313.90	25574.0	40.918

ns, *, **: Not significant, significant at p<0.05 or p<0.01, respectively, SED: Standard error of difference between means. One-way ANOVA

Table 5: Correlation matrix of some cassava plant characters (above diagonal) and some vegetable cowpea plant characters (below diagonal)

Cassava characters	Fresh root yield (Mt ha^{-1})	Weight marketable tubers (kg)	Root/shoot ratio	Number leaves plant^{-1} (12 WAP)	Plant height (cm) (12 WAP)	Vegetable cowpea characters
Fresh root yield (Mt ha^{-1})	1.00	0.74**	0.50**	-0.05ns	0.17ns	Fresh pod yield (Mt ha^{-1})
Weight marketable tubers (kg)	0.29ns	1.00	0.33ns	-0.25ns	0.14ns	Number pods plant^{-1}
Root/Shoot ratio	1.00**	0.29ns	1.00	0.096ns	0.06ns	Fresh pod weight plant^{-1} (g)
Number leaves plant^{-1} (12 WAP)	0.73**	0.38ns	0.73**	1.00	0.26ns	Plant biomass (kg)
Plant height (cm) (12 WAP)	-0.15ns	0.01ns	-0.15ns	-0.21ns	1.00	Number leaves plant^{-1} (12 WAP)
	Fresh pod yield (Mt ha^{-1})	Number pods plant^{-1}	Fresh pod weight plant^{-1} (g)	Plant biomass (kg)	Number leaves plant^{-1} (12 WAP)	

ns: **Correlation not significant or significant at p<0.01(2-tailed), respectively. Above and below diagonals indicate the correlation matrix of the variables of cassava and vegetable cowpea, respectively

($p\leq 0.01$) correlation with fresh root yield of cassava with correlation coefficients (r) of 0.74 and 0.50, respectively. The other variables (number of leaves plant^{-1} and plant height) were not significantly ($p\geq 0.05$) correlated with all the variables evaluated. In vegetable cowpea, positive and highly significant ($p\leq 0.01$) correlation was recorded between fresh pod weight plant^{-1} and fresh pod yield, plant biomass and fresh pod yield as well as plant biomass and fresh pod weight plant^{-1} with r = 1.00, 0.73 and 0.73, respectively.

Analyzed core soil samples after total crop harvest (Table 6) indicated significant ($p<0.05$) variations in soil pH, total nitrogen (N), available phosphorus (Av. P), organic matter (OM) and base saturation (BS) among the treatments. Mono-cropped cowpea had the highest pH value, total

Table 6: Effect of sequential planting of vegetable cowpea on soil pH and other chemical properties in mono- and intercrop after total crop harvest

Treatments	pH (1:2.50, Soil: H20)	Total N (%)	Av. P (mg kg^{-1})	OM (%)	BS (%)
Monocropped NR 8082	5.13^{bc}	0.013^{b}	16.73^{cde}	1.28^{c}	78.35^{b}
Monocropped TMS 30574	4.69^{bc}	0.019^{b}	15.53^{de}	1.33^{c}	69.19^{c}
Monocropped TME 419	4.98^{c}	0.021^{b}	12.23^{e}	1.53^{c}	79.48^{b}
Monocropped TMS 98/0505	4.96^{bc}	0.027^{b}	19.90^{cde}	1.30^{c}	67.52^{c}
Monocropped cowpea	6.34^{a}	0.217^{a}	31.33^{a}	3.36^{a}	90.78^{ab}
NR 8082//cowpea	5.56^{b}	0.056^{b}	23.63^{bc}	2.25^{b}	81.21^{b}
TMS 30572//cowpea	5.59^{b}	0.041^{b}	22.33^{bcd}	2.56^{b}	83.09^{ab}
TME 419//cowpea	5.61^{b}	0.064^{b}	23.07^{bcd}	2.33^{b}	82.42^{ab}
TMS 98/0505//cowpea	5.42^{bc}	0.062^{b}	27.93^{ab}	2.50^{b}	87.78^{a}
SED	0.3270	0.02151	3.368	0.3247	4.009
ANOVA GLM					
Treatment	*	**	**	**	**
Mean square	0.7222	0.0117696	109.67	1.5978	175.85

Means in the same column with the same letter do not differ significantly at *$p \leq 0.05$, **$p \leq 0.01$. SED: Standard error of difference between means. One-way ANOVA

Table 7: Effect of sequential planting of vegetable cowpea on some soil chemical properties in mono- and intercrop after total crop harvest

Treatments	Na^{+}	K^{2+}	Mg^{2+}	Ca^{2+}	EA	ECEC
	(cmol (+) Kg^{-1})					
Monocropped NR 8082	0.167^{ab}	0.024^{b}	0.67^{b}	1.70^{cd}	0.72^{b}	4.70^{bc}
Monocropped TMS 30574	0.158^{b}	0.048^{b}	0.93^{b}	1.70^{cd}	0.85^{b}	4.55^{c}
Monocropped TME 419	0.151^{ab}	0.010^{ab}	0.80^{b}	1.17^{d}	0.77^{b}	4.33^{c}
Monocropped TMS 98/0505	0.153^{b}	0.055^{b}	1.03^{b}	1.77^{cd}	0.85^{b}	4.47^{c}
Monocropped cowpea	0.189^{a}	0.220^{a}	1.97^{a}	3.20^{a}	1.48^{a}	5.45^{ab}
NR 8082//cowpea	0.171^{ab}	0.056^{b}	1.33^{ab}	2.60^{ab}	1.15^{ab}	4.86^{abc}
TMS 30572//cowpea	0.173^{ab}	0.060^{b}	1.33^{ab}	3.20^{a}	1.04^{ab}	5.13^{abc}
TME 419//cowpea	0.167^{ab}	0.062^{b}	1.20^{b}	1.90^{bcd}	0.93^{b}	5.45^{ab}
TMS 98/0505//cowpea	0.174^{ab}	0.065^{b}	1.33^{ab}	2.30^{bc}	0.85^{b}	5.69^{a}
SED	0.01308	0.0614	0.3245	0.3158	0.2185	0.3664
ANOVA GLM						
Treatment	*	*	*	**	*	*
Mean square	0.0004296	0.0100074	0.4425	1.0558	0.16459	0.7192

Means in the same column with the same letter do not differ significantly at *$p \leq 0.05$, **$p \leq 0.01$. SED: Standard error of difference between means. One-way ANOVA

N, available P, OM and BS, relative to the other treatments in both mono- and intercrops. The results further showed that all the soil parameters evaluated were generally higher in the intercrops and mono-cropped vegetable cowpea compared to the initial values obtained prior to planting. The intercropped plots had higher pH values, total N, available P, OM and BS relative to the mono-cropped cassava plots, except mono-cropped vegetable cowpea.

One-way analysis of variance of soil samples that were collected and subjected to standard laboratory analysis after crop harvests (Table 7) indicated significant variations in exchangeable bases (Na^{+}, K^{2+}, Mg^{2+} and Ca^{2+}), exchangeable acidity (EA) and effective cation exchange capacity (ECEC). The soil exchangeable bases and ECEC were high in mono- and intercropped cowpea with sequential planting, especially mono-cropped cowpea compared with mono-cropped cassava. In contrast, EA were higher in mono-cropped cassava genotype plots relative to their corresponding intercropped plots and mono-vegetable cowpea plot.

In contrast to partial land equivalent ratio (LER), (Table 8) total LER were all above unity, indicating higher yield productivity in the intercropped system. The crop mixture cassava NR 8082//cowpea gave the highest LER, which was higher by 8, 16 and 14 percent compared with TMS 30572//cowpea, TME 419//cowpea and TMS 98/0505//cowpea mixes, respectively. This implies that an LER>unity could result from low inter-specific competition or strong facilitation among the component crops in the mixes. Land equivalent coefficient (LEC) indicated that intercropped TME 419//cowpea gave the lowest LEC while TMS 8082//cowpea recorded the highest LEC. Competitive ratio (CR) showed cassava as not only the aggressive crop in the system but also the dominant component as an erectophile that ramified much of the aerial space in the intercropping situation while percentage land saved indicated NR 8082//cowpea intercrop had the largest amount of land saved, which was higher by 19, 40 and 34 % relative to TMS 30572//cowpea, TME 419 and TMS 98/0505//cowpea intercrops, respectively.

The economic assessment indicated that mono-cropping had better partial gross monetary returns (GMRs) than the crop mixes (Table 9). However, total GMRs for the intercropping system was higher relative to their

Table 8: Effect of sequential planting of vegetable cowpea on biological productivity of the component crops in mono- and intercrops

Treatments	Land equivalent ratio (LER) Total‡	Partial† Cassava	Partial† Cowpea	Land equivalent coefficient (LEC)	Competitive ratio (CR) Cassava	Competitive ratio (CR) Cowpea	Land saved (%)
Monocropped cowpea	1.00	-§	1.00	-	-	-	-
Intercropped cowpea	-	-	0.54	-	-	-	-
Monocropped cassava	1.00	1.00	-	-	-	-	-
Intercropped cassava	-	0.81	-	-	-	-	
Cassava//cowpea	1.35	0.81	0.54	0.44	1.50	0.67	25.93
Monocropped NR 8082	1.00	1.00	1.00	1.00	-	-	-
Monocropped TMS 30574	1.00	1.00	1.00	1.00	-	-	-
Monocropped TME 419	1.00	1.00	1.00	1.00	-	-	-
Monocropped TMS 98/ 0505	1.00	1.00	1.00	1.00	-	-	-
NR 8082//cowpea	1.50	0.92	0.58	0.53	1.59	0.63	33.33
TMS 30572//cowpea	1.38	0.97	0.40	0.39	2.43	0.41	27.01
TME 419//cowpea	1.24	0.74	0.51	0.37	1.45	0.69	20.00
TMS 98/0505//cowpea	1.28	0.61	0.67	0.41	0.91	1.10	21.88

†Partial LER for cassava and vegetable cowpea were obtained by dividing each intercrop yield by its corresponding mono-crop yield, ‡Total LER was the sum of the partial LERs from cassava and vegetable cowpea in the intercropping system, §Dashes indicate no measurements were taken from the corresponding plots because the representative component crop (cassava or vegetable cowpea) was not planted in the plot (mono-crop)

Table 9: Effect of sequential planting of vegetable cowpea on the economic productivity of the component crops in mono- and intercrops‡

Cropping system	Gross monetary return ($ ha^{-1}) Total	Partial Cassava	Partial Cowpea	Total cost of production ($ ha^{-1})	Net return ($ ha^{-1})†	Benefit-cost ratio
Monocropped cowpea	16,404.04	-§	16,404.04	2,416.67	13,987.37	5.79
Intercropped cowpea	8,858.59	-	8,858.59	2,568.18	6,290.40	2.45
Monocropped cassava	8,242.42	8,242.42	-	2,643.94	5,598.49	2.12
Intercropped cassava	6,707.07	6,707.07	-	2,795.46	3,911.62	1.40
Monocropped NR 8082	7,717.17	7,717.17	-	2,643.94	5,073.23	1.92
Monocropped TMS 30574	7,515.15	7,515.15	-	2,643.94	4,871.21	1.84
Monocropped TME 419	4,888.89	4,888.89	-	2,643.94	2,244.95	0.85
Monocropped TMS 98/0505	13,575.76	7,070.71	9,565.66	2,643.94	10,931.82	4.13
NR 8082//cowpea	16,636.36	7,070.71	9,565.66	2,795.46	13,840.91	4.95
TMS 30572//cowpea	13,909.09	7,313.13	6,595.96	2,795.46	11,113.64	3.98
TME 419//cowpea	11,949.49	3,595.96	8,353.54	2,795.46	9,154.04	3.27
TMS 98/0505//cowpea	19,202.02	8,282.83	10,919.19	2,795.46	16,406.57	5.87

‡Cassava and vegetable cowpea were sold at current market price (₦ kg^{-1}) of ₦80 kg^{-1} and ₦200 kg^{-1}, respectively, at time of harvest. ₦ is Naira, Nigerian currency, 1 USA Dollar = ₦198:00, †Net return (NR) was the difference between total gross monetary return (TGMR) and variable total costs of production (TCP) of cassava and vegetable cowpea in the mono- and intercrop system while BCR is the ratio of NR and TCP, §Dashes indicate no measurements were taken from the corresponding plots because the representative component crop (cassava or vegetable cowpea) was not planted in that plot (Mono-crop)

mono-cropped equivalents. Among crop mixes, TMS 98/0505//cowpea intercrop had the highest monetary return while TME 419//cowpea intercrop gave the lowest financial returns in the systems. Furthermore, the results showed that higher LERs did not automatically indicate highest GMRs, net returns (NRs) nor benefit cost ratio (BCRs). The total cost of production expended in the mono-cropped plots was lower compared to mixes. The net returns among treatments showed TMS 98/0505//cowpea intercrop gave the highest net return. Except mono-cropped cowpea, whose BCR was lower compared with TMS 98/0505//cowpea, the BCRs in the crop mixes were all higher relative to their corresponding mono-crops.

The regression analysis between LER and net return (NR) indicated the relationship as poly-linear, positive (Fig. 2a), which implied that net return ($ ha^{-1}) increased as total LER increased from unity upwards up to 1.4 and then stabilized even as LER increased. The same relationship trend was exhibited between LER and benefit cost ratio (BCR). However, BCR increased as LER increased up to 1.25 and then decreased with further increase in total LER (Fig. 2b). Benefit cost ratio exhibited positive, weak linear relationship with total crop yield (cassava+vegetable cowpea, Mt ha^{-1}) with coefficient of determination (R^2), which is a measure of how well the regression line represents the whole data as 4.697 (Fig. 3a). It further explained that 47% of the total variation in total crop

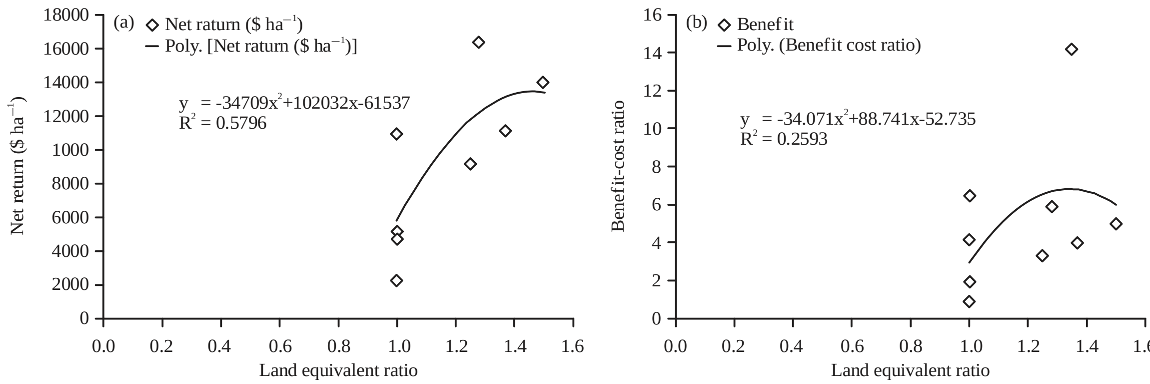

Fig. 2(a-b): Relationship between land equivalent ratio and (a) Net return ($ ha^{-1}) and relationship between land equivalent ratio and (b) Benefit cost ratio with quadratic regression lines, respectively

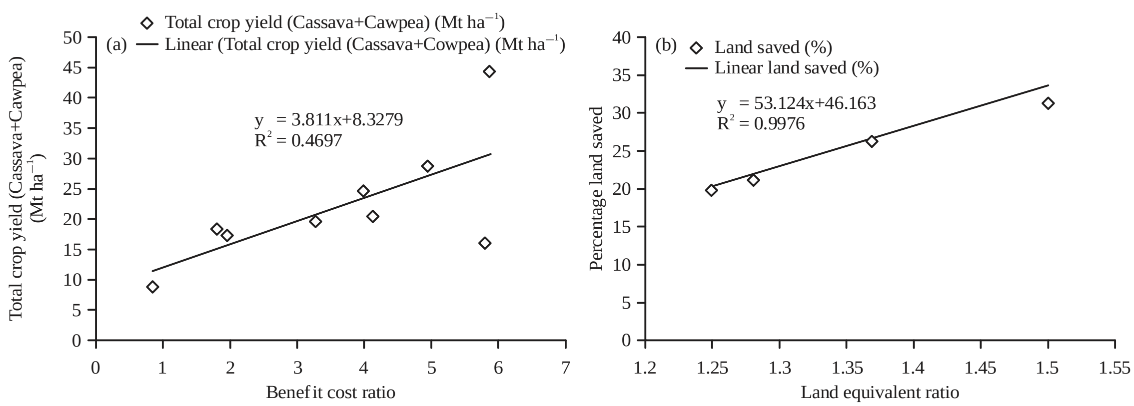

Fig. 3(a-b): Relationship between benefit cost ratio, (a) Total crop yield [(cassava+cowpea (Mt ha $^{-1}$)] and relationship between land equivalent ratio and (b) Percentage land saved with linear regression lines, respectively

yield (cassava+vegetable cowpea, Mt ha^{-1}) can be explained by the linear association between benefit cost ratio and total crop yield. Also, LER had positive and very strong linear relationship with percentage land saved ($R^2 = 0.9976$) (Fig. 3b).

DISCUSSION

The mono-cropped cassava genotype TME 419 had the smallest weight of marketable roots plant^{-1} and fresh root yield in both cropping systems compared with the other tested genotypes. The findings corroborated previous studies by Udealor and Asiegbu[48] on Cassava//vegetable cowpea (*Vigna unguiculata* L. Walp. ssp. *sesquipedalis*) in Umudike, Nigeria, Sherif and Salem[49] on cassava//fodder cowpea (*Vigna sinensis* L.) in Giza, Egypt, Mbah *et al.*[8] on cassava//soybean (*Glycine max* L. Merrill) in Umuahia, Nigeria and De Albuquerque *et al.*[50] on Cassava//cowpea (*Vigna unguiculata* L. Walp.) in Roraima, Brazil, in which they reported that intercropping was significantly beneficial to the cassava component in the system because of wide marginal variations recorded in both growth and yield variables of the crop associated with time of harvest of the component crops in which the cassava had enough time to recover from the competition it experienced after the harvest of the short seasoned legume component crop in the mix as well as benefitted from the nitrogen fixed and decomposed crop left-over (biomass) of the crop. Olasantan[51] on intercropping cassava//cowpea or maize under row arrangements, Stern[52] on nitrogen fixation and transfer in intercrop systems, San-Nai and Ming-Pu[53] on nitrogen transfer between N_2-fixing plant and non-N_2-fixing plant, Aduramigba and Tijani-Eniola[54] on cassava//groundnut (*Arachis hypogaea* L.) intercrop in their studies on planting densities as well as Udealor and Asiegbu[48] on cassava//vegetable cowpea intercrop in their various studies further reported that the leguminous crop provided not only ground cover but also conserved more moisture alongside atmospheric nitrogen fixation and mineralization of bio-materials, which was made available in the crop mixture and invariably of benefit to the companion crop (cassava) in the cropping system.

The intercropped TMS 98/0505 cassava genotype exhibited highest available P and BS in both cropping systems (mono- and intercrop) in contrast to total N and OM. The results corroborate similar works by Mugendi, *et al.*[55], Odedina *et al.*[56] as well as Mbah and Onweremadu[57] who reported significant increase in soil pH as organic matter presence in the soil increases due to cumulative increase in alkaline earth materials associated with the mineralization of the materials, thereby increasing soil fertility. The increased presence of soil nutrients in the mono-cropped vegetable cowpea and intercropped plots was due to perhaps crop left-over of the cowpea, which served as live-mulch, soil fertility enhancer through air nitrogen fixation and as a strong soil moisture conservator. Similarly, Owolabi *et al.*[58], Zhang and Li[59], Adeleye *et al.*[60] as well as Njoku and Mbah[61] submitted that the application of organic amendment enhances soil exchangeable cations, reduces exchangeable acidity and invariably increases soil base saturation, which is achieved through the process of buffering during mineralization of the organic materials.

An assessment of the productivity of the systems indicated that our findings corroborated similar biological productivity results from intercropping studies by Udealor and Asiegbu[31] on cassava//vegetable cowpea mixture, Cenpukdee and Fukai[30] on cassava//maize (*Zea mays* L.)//melon (*Citrullus colocynthis* L.) of the family Cucurbitaceae intercrop, Mutsaers *et al.*[62] on cassava-based intercropping with legumes, Olasantan *et al.*[63] on cassava//maize intercrop. Furthermore, Zhang and Li[59] on competitive and facilitative interactions in intercropping systems, Ayoola and Makinde[64] on contrasting cassava cultivars//legume intercrop, Njoku and Muoneke[35] on cowpea//cassava mixture as well as Salau *et al.*[65] on cassava//pumpkin (*Cucurbita moschata* Duchesne) intercropping systems showed that the legume or cereal component crop, which was less competitive for growth resources with the erectophile cassava at critical stages of growth of the component crop significantly contributed to yield advantage obtained in the mixes because the productivity indices were above unity relative to the monocrops.

The yield advantage achieved in the mixes could be due to better utilization of available growth resources coupled with complementary synergy between cassava an erectophile and vegetable cowpea, a planophyll and nitrogen fixer. These observations were consistent with Mbah *et al.*[8] on cassava//soybean (*Glycinemax* L. Merrill) intercropping, Udealor and Asiegbu[48] on cassava//vegetable cowpea intercrop, Njoku and Muoneke[35] oncowpea//cassava mixture as well as Nyi *et al.*[66], Ndonda *et al.*[67] in cassava and groundnut (*Arachis hypogea* L.) of the family Fabaceae intercrop in which they surmised from their various studies in diverse locations that productivity in intercropping situation becomes relevant when subjected to real monetary value vis-à-vis mono-cropping, which showed yield advantage of intercropping over monocropping. The results further showed that intercropping improved cassava root and vegetable cowpea fresh pod yield as well as the fertility of the soil hence, could be considered a reliable and economically viable system for production of the component crops under tropical agro-ecological conditions.

CONCLUSION

The results showed that intercropping NR 8082cassava cultivar with vegetable cowpea gave higher crop yields compared with the other intercrops. The bio-productivity indices (LER, LEC and %-land saved) indicated that NR 8082//cowpea intercrop exhibited highest yield advantage in the systems. However, financial analysis indicated that in terms of total gross monetary return (TGMR), net return (NR) and benefit cost ratio(BCR), TMS 98/0505//cowpea intercrop was more productive in both mono- and intercrop. Therefore, farmers in the region can be encouraged to intercrop TMS 98/0505 cassava cultivar with cowpea for sustainable higher crop and economic yield.

SIGNIFICANCE STATEMENTS

The efficiency of sequential cropping of vegetable cowpea in cassava-based cropping system depends on the morpho-type of the cassava cultivar used and the growth vigour of the vegetable cowpea. Our findings showed that intercropping NR 8082 or TMS 98/0505 cassava cultivars with vegetable cowpea was beneficial. More so, sequential cropping of vegetable cowpea in a cassava-based cropping system significantly improved the nutrient status of the soil, which was of benefit to the cassava component. Hence, the sequential cropping of the short-duration, soil fertility improving legume crops such as vegetable cowpea served as a viable avenue in reducing the cost of production, improve environmental status in cassava-legume intercrops and guarantee higher economic crop yield.

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