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EFFECT OF SOYBEAN PLANT POPULATIONS ON YIELD AND PRODUCTIVITY OF CASSAVA AND SOYBEAN GROWN IN A CASSAVA-BASED INTERCROPPING SYSTEM

[EFECTO DE LAS POBLACIONES DE PLANTAS DE SOYA SOBRE EL RENDIMIENTO Y PRODUCTIVIDAD DE YUCA Y SOYA CRECIDAS EN UN SISTEMA INTERCALADO BASADO EN YUCA]

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SUMMARY

Intercropping cassava (*Manihot esculenta* Crantz), with varying soybean [*Glycine max* (L.) Merrill] plant populations may influence not only the performance of the component crops but also the residual nitrogen contribution to the cropping system. The treatment scheme was cassava fixed at 100% of its sole crop population of 10,000 plants ha^{-1} while soybean was varied at 25, 50, 75 and 100% of its sole crop population of 266,000 plants ha^{-1}, representing 66,500; 133,000; 199,500 and 266,000 plants ha^{-1}, respectively. The experiment was laid out in a randomized complete block design with three replicates. Fresh tuber yield in cassava increased as soybean population increased to the highest amount used in the study while number of pods plant^{-1} and seed weight plant^{-1} in soybean were depressed by intercropping in the two cropping seasons. However, soybean grain yield was significantly increased with increase in population due to higher aggregate plant populations per unit area in the intercrop. Averaged over the two cropping seasons, productivity showed that cassava/soybean intercrop, especially at the highest soybean population gave the highest yield advantage in terms of total land equivalent ratio, (2.00), land equivalent coefficient (2.41), crop yield equivalent for cassava (31.07 t ha^{-1}) and for soybean (2.25 t ha^{-1}), monetary equivalent ratio (1.56), total gross monetary returns (₦170,311.52) and total net profit (₦74,488.02). This implies that for maximum financial returns, additive intercropping of cassava and soybean at 100% cassava + 100% soybean is recommended because of improved productivity of the system as well as bonus yield and improved health of the farmers from the associated soybean component are achieved.

Keywords: Cassava; *Manihot esculenta* Crantz; soybean; *Glycine max;* intercropping; plant populations; productivity.

RESUMEN

Las poblaciones de plantas en el cultivo de yuca intercalado (*Manihot esculenta* Crantz) con variedades de soya [*Glycine max* (L.) Merrill] podrían influenciar el rendimiento de los componentes del cultivo y el suministro de nitrógeno residual al sistema de cultivo. El esquema de tratamiento consistió en yuca fijado en 100% de una sola población de 10,000 plantas ha^{-1} mientras que la de soya fue variada en 25,50,75 y 100% de una sola población de 266,000 plantas ha^{-1} representando 66,500; 133,000; 199,500 y 266,000 plantas ha^{-1} respectivamente. El rendimiento de tubérculos frescos de yuca se incrementó conforme la población de soya incrementó, mientras que el número de vainas por planta^{-1} y peso de la semilla por planta^{-1}disminuyó en la soya por el intercalado en las dos temporadas. Sin embargo el rendimiento de grano en la soya se aumento con el incremento en la población debido al número de plantas que fueron agregadas por unidad de área en el intercalado. Promediando después de las dos temporadas, la productividad demostró que el intercalado de yuca/soya, especialmente en la más alta población dio el más alto rendimiento en términos de total de tierra equivalente (2.00), coeficiente de tierra (2.41), equivalente de rendimiento de cultivo para yuca (31.07 t ha^{-1}) y para la soya (2.25 t ha^{-1}), proporción monetaria (1.56), recuperación monetaria bruta (₦170,311.52), y la ganancia total neta (₦74,488.02). Esto implica que para una recuperación máxima, intercalados de yuca y soya en 100% de yuca mas 100% de soya es recomendado porque mejora la productividad del sistema así como también mejora el rendimiento y mejora las condiciones de los agricultores debido a la asociación del componente soya.

Palabras clave: Yuca; *Manihot esculenta* Crantz, Soya; *Glycine max*; Intercalado; Población de plantas; Productividad.

INTRODUCTION

Growing of two or more crops simultaneously on the same field in different but proximate stands is a common sustainable crop production system in the humid tropics (Fageria, 1992, Willey, 1979). It has been shown to be more efficient in resource utilization, and improves the overall ecology of the system (Babatunde, 2000) as well as increases monetary returns to the farmers (Mbah *et al*., 2009). According to Olasantan and Lucas, (1992) the architecture and height of crop canopy as well as days to utilization of soil and aerial environment of the plants properly contribute to the competitiveness and performance of component crops in intercropping. Furthermore, the penetration of light into plant stand is diminished through interception and absorption by the leaves and other parts of the shoot systems.

Hence, in an intercropping system, light utilization by leaf and crop surfaces determine the potential shares of the light that are gained by the component crops. Introducing legumes, including, soybean into cassava-based cropping systems in the humid tropics of south east Nigeria is gaining increased attention because soybean fix atmospheric nitrogen and produce proteins, while cassava deplete the soil nitrogen and give carbohydrates.

Cassava and soybean mixtures improve the diet of farmers as well as the soils of their farms. This study was initiated purposely to evaluate the effects of increasing soybean plant density on growth, yield and biological productivity of the crop species in the mixture as well as to assess the appropriate soybean plant density in cassava/soybean mixture.

MATERIALS AND METHODS

Field experiments were conducted at the Teaching and Research Farm, Michael Okpara University of Agriculture, Umudike, Abia State. The study area lies at Longitude 07^{o} 33' E, Latitude 05^{o} 29' N, altitude 122 m in the humid low lands of southeastern Nigeria. The area has two distinct seasons – the dry season (November – April) and the wet season (May – October). The mean annual rainfall of the experimental site was 2,179.5 mm (2001/02) and 2,069.3 mm (2002/03) and displays a bimodal pattern that is characteristics of southern part of West Africa. The mean monthly temperature during the two cropping seasons ranged from a mean minimum of 25.0 ^{o} C to a mean maximum of 28.5 ^{o} C. The vegetation is rainforest, although much has been degraded to secondary forest and fallow. The top soil of the location is a sandy loam characterized as ultisol (paleustult). The pre-planting soil analysis (0 – 15 cm) of the experimental sites is presented in Table 1.

A low branching cassava variety (TMS 30572) was obtained from National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria, while a medium maturing soybean variety (TGX-1440-IE) obtained from International Institute of Tropical Agriculture (IITA) Ibadan, Oyo state, Nigeria were used for the study. There were six treatments fitted into a randomized complete block design with three replications. The experiment was carried out under the following treatment scheme:

1. 100 % sole cassava, (10,000 plants ha^{-1})
2. 100 % sole soybean, (266,000 Plants ha^{-1})
3. 100 % sole cassava + 25 % sole soybean
4. 100 % sole cassava + 50 % sole soybean
5. 100 % sole cassava + 75 % sole soybean
6. 100 % sole cassava + 100 % sole soybean

The sole of the component crops were established as control for assessing productivity of the system. The Plot size was 4 x 5 m (20 m^{-2}) with 0.50 m inter-plot and 1.00 m inter-block spaces. Cassava and soybean were planted the same day on 5 m long ridges made 1 m apart.

Table 1: Pre-planting soil analysis of experimental sites in 2001/02 and 2002/03 cropping seasons.

Soil Property	Values	
	2001/02	2002/03
Soil texture	Sandy loam	
pH 1:1 (soil:water)	5.20	4.50
% organic carbon	1.16	1.10
% Total N	0.10	0.13
% organic matter	2.16	2.32
Available P Cmol./kg	19.0	17.0
Exchangeable Ca^{2+} Cmol./kg	2.40	1.20
Exchangeable k Cmol./kg	0.17	0.20
Effective CEC Cmol./kg	4.62	6.24

Cassava cuttings were planted slanting (45°) on the crest of the ridges, one meter apart at the recommended sole plant population of 10,000 plants ha^{-1} while soybean seeds were sown, three seeds $stand^{-1}$ at the varying plant populations as shown in the treatment scheme. Missing stands of cassava were supplied while soybean seedlings were thinned to achieve one plant $stand^{-1}$ 2 weeks after planting (WAP). Manual hoe weeding and remoulding of ridges were carried out 3, 8 and 12 WAP. Slashing of the experimental plots was done 26 WAP. Compound fertilizer N:P:K:Mg 12:12:17:2 at the rate of 400 kg ha^{-1} (Enwezor *et al*. 1989) was applied in two split doses (200 kg ha^{-1}) at 3 WAP on soybean and the second half 8 WAP on cassava.

At the different sampling ages, three cassava and five soybean stands were randomly sampled from the inner ridges of each plot. Data on plant height and number of leaves $plant^{-1}$ were taken from the component crops. Plant height of cassava and soybean was measured with a meter rule, as the height from the base of the crop (ground level) to the tip of the plant while number of leaves $plant^{-1}$ was collected by counting.

Soybean was harvested at 4 months after planting (MAP) when 95 % of the pods had turned brown by pulling whole dry plants with the roots. Harvested soybean pods were sun-dried and threshed. Cassava was harvested at 12 MAP. The yield and yield components of cassava and soybean were taken from the net plots of three inner ridges (6 m^2) in sole and intercropped plots. Records were taken on total number of fresh tubers $plant^{-1}$ and weight of tubers ha^{-1} in cassava and number of pods $plant^{-1}$, seed weight $plant^{-1}$ and grain-yield (tons ha^{-1}) in soybean.

Biological and economic efficiency of the intercropping system was assessed by comparing the productivity of a given area of intercropping with that of sole crops using the following competition functions**:**

The land equivalent ratio (LER), = $\frac{Yci}{Ycs} + \frac{Ysi}{Yss}$

Where,

Yci = Yield of cassava in intercrop

Ycs = Yield of cassava in sole crop

Ysi = Yield of soybean in intercrop

Yss = Yield of soybean in sole crop, (Mead and Willey, 1980).

Land equivalent coefficient, (LEC) =
LA x LB

Where,
LA = LER of main crop (Cassava)
LB = LER of intercrop, (Adetiloye *et al*., 1983).

Crop yield equivalent (t ha^{-1}):

$$\frac{\text{Yield of crop 'a'}}{\text{Market price of crop 'a'}} \times \frac{\text{Market price of intercrop 'a + b'}}{1}$$

Where,
'a' = Yield of cassava or soybean in sole
'a + b' = Yield of cassava and soybean in intercrop, (Prasad and Srivastava, 1991).

Monetary equivalent ratio (MER), =
($r_1 + r_2$) /R

Where,
r_1 = Monetary return of cassava in the intercrop
r_2 = Monetary return of soybean in the intercrop
R = Higher sole crop monetary return compared with the others, (Adetiloye, 1989).

Gross monetary returns (GMR) (₦ ha^{-1}) was computed for each treatment based on the prevailing market prices of the crops in the study location while net profit (₦ ha^{-1}) was calculated as the difference between GMR and the variable costs of production (Land preparation, procurement of planting materials and planting, three farm weeding and one under-brushing, fertilizer procurement and application, harvesting and processing of soybean pods, harvesting of cassava fresh tubers and movement of farm produce to the nearest food market) of the component crops.

All data from each crop were separately subjected to analysis of variance relevant to RCB experiments as outlined by Gomez and Gomez (1984). The analysis was used to compare the variability in selected growth and yield parameters, due to the treatment applications. Comparison of treatment means were detected by standard error according to Obi (2001).

RESULTS AND DISCUSSION

Cassava: In both cropping seasons, intercropping increased the number of tubers $plant^{-1}$ and fresh tuber yield of cassava ha^{-1}, though not significantly (Table 2). This could be due to better photosynthetic efficiency by intercrops than sole cassava. Also, cassava tuber initiation and bulking were not subjected to any intercrop competition, having harvested the soybean earlier before tuberization process commenced in cassava. Total number of tubers $plant^{-1}$ increased with increase in soybean plant populations. However, fresh yield of cassava was not significantly affected by soybean plant populations in the two cropping seasons, though there were bigger individual sizes of root tubers in the intercrop as soybean populations increased. The big individual roots obtained could be attributed to more competition for light and other growth resources as soybean plant population increased under the additive mixtures. The results confirmed the observations of Chinaka and Obiefuna (2000) in their study on sweet potato/maize mixture as well as Ennin *et al* (2002) in soybean/maize intercrop. Furthermore, the varying maturity dates of the component crops led to a reduction in competitive effects of soybean on cassava fresh tuber yield. Soybean matured much earlier than cassava, an indication that cassava had enough time, space and assess to growth resources such as soybean crop left-over and fixed atmospheric nitrogen to compensate for losses suffered once the soybean competition was removed. The results corroborated studies by Cenpukdee and Fukai (1992) in cassava/legume intercrop in which they reported that 30 - 50 days after planting, canopy width of and light interception by cassava were very low such that the legume in the mixture intercepted 45 – 90 % solar radiation incident reaching the crops.

Soybean: Intercropping significantly depressed the number of pods $plant^{-1}$, seed weight $plant^{-1}$ and grain yield ha^{-1} in soybean in both seasons (Table 2). The highest grain yield was obtained in sole soybean because of reduced inter-specific competition for growth resources among the crops as well as higher aggregate population density per unit area observed in the intercropping situation. In the two cropping seasons, number of pods $plant^{-1}$ and weight of seeds $plant^{-1}$ were reduced as soybean plant density increased in the mixture due to competition for growth resources between the component crops, which reduced the rate of assimilated photosynthates in high density soybean planting.

Field grain yield ha^{-1} increased as soybean plant density increased up to 199,500 plants ha^{-1}.and then decreased with further increase in plant density**.** The increase in soybean grain yield was due to better utilization of environmental factors since there was less interference from the neighboring cassava plants with initial slow growing period. The results confirmed the observations of Udealor (2002) in cassava/vegetable cowpea mixture as well as Ebwongu *et al*. (2001) in maize/*Solanum* potato intercrop in which they reported improved performance of crops with low plant population due to species intercrop effects.

Assessment of the productivity of the system:

Biological: The land equivalent ratio (LER), land equivalent coefficient (LEC) and yield equivalent of cassava and soybean were used to assess the biological productivity of the component crops in the intercrop (Table 3). In the two cropping seasons, intercropping resulted in yield advantage. The total LER of cassava and soybean in the intercrop were all above unity, ranging from 1.53 to 1.99 (2001/02) and 1.53 to 2.01 (2002/03), an indication that higher productivity per unit area was achieved in intercropping than sole cropping. In particular, 100 % cassava + 100 % soybean combination gave the highest total LER of 1.99 (2001/02) and 2.01 (2002/03), implying that 99 % and 101 % in 2001/02 and 2002/03, respectively more land would be required as sole crop to produce the yield obtained under intercropping situations. Yield advantages resulted from intercropping because the component crops had different durations and growth patterns, hence, made major demands on resources at different times, which led to better temporal use of growth resources (Mbah and Muoneke, 2007).

Value obtained in LEC and yield equivalent of the component crops followed a trend similar to that of LER showing that intercropping cassava and soybean had strong yield advantage relative to sole cropping of the component crops in both cropping seasons.

These productivity results (LER, LEC and Yield equivalent) are consistent with the findings of Njoku *et al*. (2007) in sweet potato/okra, Muoneke *et al*. (2007) in maize/soybean, John and Mini (2005) in okra/cowpea, okra/cucumber and okra/amaranth intercrops as well as Mbah *et al* (2009) in cassava/soybean mixtures, which showed yield advantages in the systems.

Economic: Assessing the monetary equivalent ratio (MER) (Adetiloye, 1989), the results showed that in either of the two cropping seasons, increased soybean plant populations increased MER in the intercropping system (Table 4). In all the combinations, MER was above unity, an indication that it was more advantageous to plant the crops in mixture than sole cropping. Intercropping 100 % cassava with 100 % soybean gave the highest percent MER (63 %) in 2001/02 and (49 %) in 2002/03. In terms of gross monetary returns (GMR), increased soybean plant population increased partial GMR in cassava and soybean.

Table 2: Effect of soybean plant populations on yield indices of cassava and soybean in cassava-based intercropping system in 2001/02 and 2002/03 cropping seasons.

Crop	Yield index	100 % sole cassava, (10,000 plants ha^{-1})	100 % sole soybean, (266,000 Plants ha^{-1})	100 % sole cassava + 25 % sole soybean	100 % sole cassava + 50 % sole soybean	100 % sole cassava + 75 % sole soybean	100 % sole cassava + 100 % sole soybean	**s.e.**
2001/02								
Cassava	No. of tubers plant^{-1}	6.47	-	7.27	7.59	9.03	9.04	0.182
	Fresh root tuber Yield (t ha^{-1})	19.7	-	20.8	21.5	21.9	23.8	0.346
Soybean	No. of pods plant^{-1}	-	40.38	31.23	22.90	17.17	15.25	2.276
	Seed weight (g plant^{-1})	-	8.97	7.00	5.09	3.93	3.34	0.704
	*Grain yield (kg ha^{-1})	-	745.90	351.87	413.02	470.35	583.62	58.085
2002/03								
Cassava	No. of tubers plant^{-1}	6.65	-	6.81	7.93	8.58	10.01	0.491
	Fresh root tuber Yield (t ha^{-1})	21.1	-	21.3	21.8	22.0	24.1	0.961
Soybean	No. of pods plant^{-1}	-	33.26	26.26	20.92	16.40	13.70	2.273
	Seed weight (g plant^{-1})	-	5.20	4.05	3.22	2.12	1.78	0.416
	*Grain yield (kg ha^{-1})	-	540.19	254.24	303.39	367.87	437.53	55.733

s.e. = standard error of means; *Grain yield at 13% moisture content.

The trend was the same in both cropping seasons. The mean of total GMR obtained from the intercropping system was greater than that from the sole of the component crops (cassava and soybean) by 31 % and 62 %, respectively in 2001/02 and by 25 % and 73 %, respectively in 2002/03. Averaged over the two cropping seasons, the highest GMR was obtained under 100 % cassava intercropped with 100 % soybean (₦170,311.52). This implies that yield and monetary returns of cassava and soybean in the intercrop were optimized at this soybean plant population.

The highest total net returns was obtained from 100 % cassava intercropped with 100 % soybean (₦66,420.64) in 2001/02 and (₦82,555.40) in 2002/03. A plausible explanation is better utilization of the resources in the micro-climate of the intercrop and the economic values of the component crops used in the study.

CONCLUSION

On the strength of the present results, soybean intercropped with cassava, especially, at 100 % of its sole crop density can be advocated as a promising intercrop in cassava-based production systems. The intercrop system gave full benefit of the main crop (cassava) while soybean yield was added productive advantage. Also, farmers' health was enhanced.

Table 3: Effect of soybean plant populations on land equivalent ratio, land equivalent coefficient and crop yield equivalent of cassava and soybean in cassava-based intercropping system in 2001/02 and 2002/03 cropping seasons.

Treatments	Land equivalent ratio			Land equivalent coefficient	Crop yield equivalent ($t\ ha^{-1}$)	
	† Partial		‡ ‡Total			
	Cassava	Soybean			Cassava	Soybean
2001/02						
100 % sole cassava, (10,000 plants ha^{-1})	1.00	-	1.00	-	-	-
100 % sole soybean, (266,000 Plants ha^{-1})	-	1.00	1.00	-	-	-
100 % sole cassava + 25 % sole soybean	1.06	0.47	1.53	1.62	25.87	1.80
100 % sole cassava + 50 % sole soybean	1.09	0.55	1.64	1.79	27.45	1.91
100 % sole cassava + 75 % sole soybean	1.11	0.63	1.74	1.93	28.67	1.99
100 % sole cassava + 100 % sole soybean	1.21	0.78	1.99	2.41	32.20	2.24
2002/03						
100 % sole cassava, (10,000 plants ha^{-1})	1.00	-	1.00	-	-	-
100 % sole soybean, (266,000 Plants ha^{-1})	-	1.00	1.00	-	-	-
100 % sole cassava + 25 % sole soybean	1.06	0.47	1.53	1.62	24.69	1.85
100 % sole cassava + 50 % sole soybean	1.08	0.56	1.64	1.77	25.85	1.94
. 100 % sole cassava + 75 % sole soybean	1.09	0.68	1.77	1.93	26.90	2.02
100 % sole cassava + 100 % sole soybean	1.20	0.81	2.01	2.41	29.93	2.25

† Partial LER for cassava and soybean were obtained by dividing each intercrop yield by its corresponding sole crop yield.
‡Total LER was the sum of the partial LERs from cassava and soybean in the intercropping system.

Table 4: Effect of soybean plant density on crop equivalent coefficient, gross monetary returns and net profit of the component crops in cassava-based intercropping system in 2001/02 and 2002/03 farming seasons.

Treatment	*Monetary equivalent ratio	+Gross monetary return (₦ ha^{-1})			Net return (₦ ha^{-1})		
		Partial			**‡‡partial**		
		Cassava	**Soybean**	**Total**	**Cassava**	**Soybean**	****Total**
2001/02							
100 % sole cassava, (10,000 plants ha^{-1})	1.00	98,5000	-	98,500	29,200.00	-	29,200
100 % sole soybean, (266,000 Plants ha^{-1})	1.00	-	53,704	53,704	-	16,204	16,204
100 % sole cassava + 25 % sole soybean	1.31	104,000	25,334	129,334	43,600.00	1,934	45,534
100 % sole cassava + 50 % sole soybean	1.39	107,500	29,737	137,237	47,100.00	3,987	51,087
100 % sole cassava + 75 % sole soybean	1.46	109,500	33,865	143,365	49,100.00	5,995	55.095
100 % sole cassava + 100 % sole soybean	1.63	119,000	42,020	161,020	58,600.00	7,820	66,420
2002/03							
100 % sole cassava, (10,000 plants ha^{-1})	1.00	120,600	-	120,600	42,100	-	42,100
100 % sole soybean, (266,000 Plants ha^{-1})	1.00	-	43,215	43,215	-	5,765	5,765
100 % sole cassava + 25 % sole soybean	1.23	127,800	20,339	148,139	64.200	539	64,739
100 % sole cassava + 50 % sole soybean	1.29	130,800	24,271	155,071	67,200	1,071	68,271
100 % sole cassava + 75 % sole soybean	1.34	132,000	29,429	161,429	68,400	1,829	70,229
100 % sole cassava + 100 % sole soybean	1.49	144,600	35,002	179,602	81,000	1,555	82,555

*Monetary equivalent ratio (MER) of intercropped cassava and soybean was obtained by dividing the monetary returns of each intercrop by the highest sole crop monetary return.
+Cassava and soybean were sold at the prevailing market prices (₦ ton^{-1}) of ₦5,000 ton^{-1} and ₦72,000 ton^{-1}, respectively at the time of harvest in 2001/02 and at ₦6,000 ton^{-1} and ₦80,000 ton^{-1}, respectively at the time of harvest in 2002/03, cropping seasons. 1 US Dollar = ₦120:50 (Nigerian Naira) in 2001/02 and ₦128:50 (Nigerian Naira) in 2002/03.
‡‡Partial net profit was the difference between partial GMR and partial variable costs of production of cassava and soybean in the intercrop.

**Total net profit was the sum of the partial net profit from cassava and soybean in the intercrop.

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