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RELATIVE PERFORMANCE OF THREE SWEET POTATO VARIETIES IN SOLE AND INTERCROP SYSTEMS IN SOUTHERN GUINEA SAVANNA ECOLOGY OF NIGERIA

Strictly as per the compliance and regulations of :

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Keywords : sweet potato, pigeonpea, planting pattern, productivity.

I. Introduction

Sweet potato (*Ipomea batatas* (L.) Lam) has a long history to stave off famine – especially as a cheap source of calories (Adam, 2005). It feeds millions of people in the developing world and it is especially popular among farmers with limited resources. The production, marketing and utilization of sweet potato have expanded in the last decade to almost all ecological zones in Nigeria (NRCRI, 2009). Presently, 381,000 – 510,000 ha of land are subjected to sweet potato cultivation in Nigeria with an annual production figure of 3.46 million metric tonnes (NRCRI, 2008). Estimated yields of sweet potatoes in the research fields varied from 40 to 70 t/ha for improved varieties, while in multilocational trials yields averaged 23.5t/ha across seasons and locations (Tewe *et al.*, 2003).

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Today, Nigeria is the largest producer of sweet potato in Africa and the second largest in the world after China. In Benue State, Nigeria, approximately 212,840 ha was subjected to sweet potato production with a mean yield of 9.80 t/ ha in 2008 (BNARDA, 2008).

Sweet potatoes are usually consumed without special processing. The fresh tuber is boiled, roasted, baked, or fried as chips, which may be sold as snacks or salted and eaten as potato crisps in most parts of Nigeria. Sweet potatoes are fed to livestock or processed industrially into alcohol, starch, noodles, candy, desserts and flour. Orange flesh sweet potatoes are rich in B – carotene (precursor for vitamin A). Sweet potatoes are now being used in Africa to combat a widespread vitamin A deficiency in 250,000 – 500,000 children. About two-thirds of the children developing xerophthalmia, resulting from lack of vitamin A, die within a year of losing their sight. The strategy of increasing orange flesh sweet potato consumption helps to alleviate vitamin A deficiency (Anderson *et al.*, 2007).

Intercropping sweet potato with pigeonpea will not only ensure better environmental resource utilization, but should also provide better yield stability, reduce pests and diseases and diversify rural income. Some yield advantages have been derived from sweet potato intercropping with okra (Njoku *et al.*, 2007) and sweet potato with pigeonpea (Egbe and Idoko, 2009). Intercropping sweet potato with pigeonpea is presently not popular but it has enormous potential in the Southern Guinea Savanna ago-ecological zone of Nigeria to ensure the supply of dietary carbohydrate, protein, fats, vitamins and minerals (calcium, magnesium, copper, iron and zinc) for the rural household (Egbe, 2005). Recently, several improved varieties of sweet potato have been introduced into the cropping systems of smallholder farmers in Benue State, particularly from International Institute of Tropical Agriculture (IITA), Ibadan and the National Root Crops Research Institute (NRCRI), Umudike. Farmers in Benue State who intercrop or mix sweet potato with pigeonpea do so in highly variable planting patterns with resultant low productivity. The study reported here was undertaken to document the influence of cropping systems on the yield and yield components of newly introduced sweet potato varieties with a view to improve the productivity of sweet potato/pigeonpea intercropping in Benue State and enhance food security of the region. The work also sought to evaluate the suitability of these newly introduced sweet potato varieties to sole, row- and strip-intercropping systems usually adopted by farmers in Benue State and in the Southern Guinea Savanna agro-ecological zone of Nigeria.

II. Materials and Methods

A field experiment was conducted for two cropping seasons (2009 and 2010) at the Teaching and Research Farm of the University of Agriculture, Makurdi [Latitude 07^o 45$^/$ - 07^o 50$^/$ N, Longitude 08^o 45$^/$ - 08^o 50$^/$ E,elevation 98 m] in Benue State, located in the Southern Guinea Savanna of Nigeria. The site used for the experiment had been cropped to pigeonpea for two years; it received 1402.50 mm of rain in 2009 and 1115.30 mm in 2010. The soil was classified as Dystric Ustropept (USDA).The same site was used for the experiment in each year. Eight core samples of soil were collected from different parts of the experimental field from a depth of 0-30 cm and bulked into a composite sample and used for the determination of the physical and chemical properties of the soil (see Table 1) before planting. The soil samples were air-dried at room temperature for one week, ground (using mortar and pestle) to pass through a 0.3 mm screen for chemical analysis. Mechanical analysis was carried out by the hydrometer method described by Bouyoucos (1962). Soil pH was obtained using a 1:2.5 soil-water ratio. Total organic carbon was determined by the use of an improved chromic acid digestion and spectrophotometric method (Heanes, 1984) and organic matter was estimated by multiplying the organic carbon figure by 1.724. Available phosphorus was determined by using Bray1 procedure (Bray and Kurtz, 1945). Nitrogen in soil was estimated by phenols colour formation method (Chaykin,1969) after micro-Kjeldahl digestion;exchangeable potassium and calcium were determined using the methods described by Jou (1983). Magnesium was assessed using the methodology developed by Tel and Rao (1982). Effective cation exchangeable capacity (ECEC) was obtained by the summation method.

Table 1: Physical and chemical properties of the surface soil (0-30 cm) at the experimental site in Makurdi in 2009 and 2010.

	Makurdi	
Parameter	2009	2010
Sand (%)	68.00	68.20
Silt (%)	13.20	16.20
Clay (%)	18.60	15.60
Textural class	Sandy loam	Sandy loam
pH (H_2O)	6.40	6.25
Organic matter (g kg^{-1})	4.25	3.73
Total N (g kg^{-1})	1.91	1.70
Available P (cmol kg^{-1} soil)	8.88	7.33
Ca^{2+} (cmol kg^{-1} soil)	3.55	2.8
Mg^{2+} (cmol kg^{-1} soil)	2.13	1.25
K^+ (cmol kg^{-1} soil)	0.44	0.41
Na^+ (cmol kg^{-1} soil)	0.19	0.17
ECEC (cmol kg^{-1} soil)	4.87	5.21

The plot was ploughed, harrowed and ridged before laying the experiment as a 3 x 5 split plot set out in a randomized complete block design with three replications. The main plot treatments comprised of three planting patterns: (i) sole cropping (sweet potato, pigeonpea *var. igbongbo*) (ii) row intercropping (sweet potato + pigeonpea) and (iii) strip intercropping (sweet potato + pigeonpea). The sub – plot treatments comprised of five improved sweet potato varieties obtained from the National Root Crops Research Institute, Umudike [TIS 87/0087, TIS 86/0356, TIS 2532.OP.1.13, 440293 (orange flesh) and 199004-2]. TIS 87/0087, though improved, was used as the local check in this study, because it had proved superior to other varieties of sweet potato in previous work (Egbe and Idoko, 2009) and it is already being grown by many farmers in the region. The gross plot was made up of four ridges,4 m long (16 m^2),while the bordered area had two ridges 3 m long (6 m^2).The experiment was planted on 25th July, 2009 and 30th July, 2010. Sweet potato cuttings measuring 25 cm with at least four nodes were planted at the crest of ridges at a spacing of 1 m x 0.3 m (33,000 plants per hectare – sole cropping, row intercropping and strip intercropping). Strip-intercropped plots had a ratio of 2 ridges of sweet potatoes: 2 ridges of pigeonpea. The pigeonpea (*var.igbongbo*) seeds used for the study were obtained from the local market in Otobi. Sole, row- and strip-intercropped pigeonpea was planted at a spacing of 1 m x 0.3 m with two seeds per hole and later thinned to 1 plant/stand (33,000 plants/ha) at 10 days after planting. While row-intercropped pigeonpea was sown by the side of the ridge, sole and strip-intercropped pigeonpea was planted at the crest of the ridge. Weeding was done at three weeks after planting (w.a.p.) and at 6 w.a.p.using traditional hand hoes.

Neither fertilizer nor insecticide was applied. This was done in accordance with standard practices of organic sweet potato production (Adam, 2005). It was expected that residual nitrogen (N) from previous pigeonpea (fixation and decomposition of leaf litter) and from the current crop would suffice. Residual benefits of pigeonpea to cassava had been reported to give higher fresh tuber yields than fallow plots in both sole and intercropping systems irrespective of NPK;15:15:15 fertilizer rates (0,45,90 kg/ha)used (Egbe et al.,2011). Muktar et al. (2010) had also indicated that N requirement for commercial sweet potato production in Nigeria was fairly low. Pigeonpea can fix up to 164.82 kg N/ha (Egbe, 2007) and can increase the available phosphorus pool in the cropping systems in which it is grown (Ae *et al.*, 1990).

At harvest, the following parameters were measured from the net plot :

(a) Sweet potato component: Number of branches/plant, number of saleable tubers/plant, weight of saleable tubers (weight of tuberous root ≥ 100g, devoid of insect and disease attack as well as harvest injuries), tuber length, tuber circumference at the widest point and fresh fodder weight.

(b) Pigeonpea component: Number of pods/plant, seeds/pod (average of five plants per plot), pod weight and grain yield.

Intercrop advantage was calculated by determining: Land equivalent ratio (LER) (Ofori and Stern, 1987). LER = (Yab/Yaa) + (Yba/Ybb),where *Y*aa and *Y*bb are yields as sole crops of sweet potato and pigeonpea, respectively and *Y*ab and *Y*ba are yields as intercrops of sweet potato and pigeonpea, respectively. Values of LER greater than 1 are considered advantageous. Land equivalent coefficient (LEC),a measure of interaction concerned with the strength of the intercrop relationship was also calculated: LEC = La x Lb, where, La = LER of main crop (sweet potato) and Lb = LER of intercrop (pigeonpea) (Adetiloye *et al.*,1983). For a two-crop mixture the minimum expected productivity coefficient (PC) is 25%, i.e. a yield advantage is obtained if LEC value exceeds 0.25. Also, the competitive ratio (CR) (Putnam *et al.*, 1984), the number of times by which one component crop is more competitive than the other was computed. Ra = La/Lb x zba/zab, where R*a* is the competitive ratio of crop *a* and L*a* and L*b* are the LERs of crops a and b respectively, zba is the proportion of crop *a* in the ab intercrop and z*a*b is the proportion of crop *b* in the ab intercrop. If R*a* < 1, there is a positive benefit and the crop can be grown in association; if Ra > 1, there a negative benefit. The reverse is true for Rb. Area x Time equivalent ratio (ATER) (Hiebisch and Mc Collum, 1987),the ratio of number of hectare-days required in monoculture to the number of hectare-days used in the intercrop to produce identical quantities of each of the components was calculated: ATER = (Rya x ta) + (Ryb x tb)/ T, where, Ry = relative yield of species 'a' or 'b' i.e., yield of intercrop/yield of monocrop,t = duration (days) for species 'a' or 'b' and T = duration (days) of the intercropping system. Values of ATER greater than 1 are considered advantageous (Ofori and Stern,1987).

Year x treatment interactions were not significant, so data for both years were pooled together and analyzed. Data collected were analyzed using GENSTAT Release 11.1 (PC/Windows) (2008.VSN International Ltd., London) and the least significant difference (LSD) test at 5% probability level was used to compare the treatment means.

III. Results

The main effects of planting patterns on some of the parameters (number of branches and saleable tubers per plant, fresh fodder weight, tuber length, circumference and saleable weight) was significant($P \leq 0.05$),but planting pattern x variety interaction effects on the various parameters of sweet potato intercropped with pigeonpea in Makurdi were not. Table 2 presents the results of the main effects of planting pattern on the number of branches and saleable tubers per plant, fresh fodder weight, tuber length, circumference and weight of sweet potato intercropped with pigeonpea. Planting pattern did not exert any significant effects on the fresh fodder weight and number of sale able tubers of sweet potato, but sole cropped sweet potato produced significantly higher number of branches per plant and saleable tuber weight than both row-intercropped and strip-intercropped treatments. Tuber length of sole cropped sweet potato was significantly higher than that of row intercropping, but it was not significantly different from that produced by strip-intercropped treatment. Tuber circumference of sole cropping was significantly lower than that of strip-intercropping, but it was statistically at par with that produced by row intercropping. Percentage reduction in saleable tuber yield of sweet potato varied from 47.07% (strip – intercropping) to 49.11% (row – intercropping).

Table 2 : Effect of cropping systems on number of branches and tubers per plant, fresh fodder weight, tuber length, circumference and saleable weight of sweet potato intercropped with pigeonpea in Makurdi.

Parameter	Sole cropping	Row- intercropping	Strip-intercropping	Mean	FLSD(0.05)
Branches/plant	5.47	3.60	5.00	4.69	0.15
Fresh fodder weight (t/ha)	1.77	1.12	1.66	1.52	ns
Tubers/plant	2.93	2.13	2.33	2.46	ns
Tuber length (cm)	21.80	15.20	16.50	17.33	5.44
Tuber circumference (cm)	22.90	20.60	24.41	22.64	2.23
Saleable tuber weight (t/ha)	11.20	5.70	6.60	7.83	3.65
Percentage Saleable tuber weight reduction (%)	0.00	49.11	41.07		

FLSD: Fisher's Least Significant Difference Test

The main effect of variety on the number of branches and tubers per plant, fresh fodder weight, tuber length, circumference and weight was significant. Table 3 shows the effect of variety on the tuber yield and other yield components of sweet potato intercropped with pigeonpea in Makurdi. Mean number of branches per plant of sweet potato varieties was 4.69. TIS 2532.OP.1.13 had significantly fewer branches/plant than TIS 87/0087, but the number of branches/plant of TIS 2532.OP.1.13 was not significantly different from those produced by 440293. TIS 87/0087 and TIS 2532.OP.1.13 consistently had significantly more number of tubers/plant, fresh fodder weight, tuber length, circumference and saleable tuber weight than all other varieties, except TIS 86/0356, which obtained similar number of tubers and tuber circumference. The length of tuber of TIS 86/0356 was significantly lower than that of TIS 2532.OP.1.13. TIS 87/0087 and TIS 2532.OP.1.13 produced similar saleable tuber weights (14.20 t/ha and 16.00 t/ha, respectively) and these were significantly higher than the saleable tuber weights produced by TIS 86/0356, 440493 and 199004-2. The latter variety gave the lowest number of tubers per plant, fresh fodder weight, tuber length, circumference and saleable tuber weight.

Table 3 : Influence of variety on the number of branches and tubers per plant, fresh fodder weight, tuber length, circumference and weight of sweet potato in Makurdi.

Variety	Branch/plant	Tubers/plant	Fresh fodder	Tuber length(cm)	Tuber circumference (cm)	Saleable tuber weight (t/ha)
TIS 87/0087(check)	5.56	3.33	2.43	20.90	24.00	14.20
TIS 86/0356	4.89	3.22	1.31	17.70	21.10	5.40
TIS 2532.OP.1.13	4.33	3.00	2.40	29.10	25.80	16.00
440293	3.67	1.56	1.05	12.40	19.90	2.50
199004-2	5.00	1.22	0.40	9.20	12.30	1.20
Mean	4.69	2.47	1.51	17.86	20.62	7.86
FLSD (0.05)	0.80	1.21	0.68	7.05	6.89	7.11

FLSD : Fisher's Least Significant Difference Test

Sweet potato varieties did not influence the number of pods produced per plant of intercropped pigeonpea (Table 4). Sole crop pigeonpea gave highest number of seeds per pod. There was, however, no significant difference between sole pigeonpea and pigeonpea row – intercropped with TIS 86/0356 or strip – intercropped with TIS 87/0087, 440293 and 199004-2. Intercropping reduced the pod weight and grain yield of pigeonpea when compared to the sole crop treatment (Table 4). Sole crop pigeonpea produced the highest pod weight (3.00 t/ha) and grain yield (2.61 t/ha), while row-intercropped pigeonpea with 440293 had the lowest pod weight (1.53 t/ha) and grain yield (1.22 t/ha).

Table 4 : Number of pods per plant, seeds per pod, pod weight (t/ha) and grain yield of sole and pigeonpea intercropped with sweet potato in Makurdi.

Cropping systems	Pods/plant	Seeds/pod	Pod weight (t/ha)	Grain yield (t/ha)
Sole pigeonpea	107.70	5.33	3.00	2.61
TIS 87/0087 row - intercropped with pigeonpea	90.70	4.00	1.56	1.28
TIS 86/0356 row – intercropped with pigeonpea	107.20	5.00	1.58	1.47
TIS 2532.OP.1.13 row – intercropped with pigeonpea	93.70	4.33	1.92	1.58
440293 row – intercropped with pigeonpea	96.50	4.00	1.53	1.22
199004-2 row – intercropped with pigeonpea	91.30	4.00	1.56	1.28
Mean (row-intercropping)	95.88	4.27	1.63	1.37
TIS 87/0087 strip - intercropped with pigeonpea	92.70	5.00	1.75	1.56
TIS 86/0356 strip – intercropped with pigeonpea	105.00	4.33	1.94	1.86
TIS 2532.OP.1.13 strip – intercropped with pigeonpea	107.70	4.33	2.11	1.83
440293 strip – intercropped with pigeonpea	101.70	5.00	1.97	1.58
199004-2 strip – intercropped with pigeonpea	94.70	5.00	2.03	1.78
Mean (strip-intercropping)	100.36	4.73	1.96	1.72
Grand Mean	99.00	4.58	1.90	1.64
FLSD (0.05)	ns	0.61	0.28	0.32

FLSD : Fisher's Least Significant Difference Test

There were no significant differences between the various treatments in LER (land equivalent ratio) and LEC (land equivalent coefficient) produced by intercropped sweet potato with pigeonpea in Makurdi (Table 5). All intercrop combinations had LER figures above unity, except row - and strip - intercropped TIS2532.OP.1.13. Also, LEC values were greater than 0.25 in all intercrop situations, except in row - and strip - intercropped TIS2532.OP.1.13. Row – intercropped 199004-2 had the highest LER (1.97) and LEC (0.75) figures, while row – intercropped TIS 2532.OP.1.13 had the lowest LER (0.97). Strip –inter cropped TIS 2532.OP.1.13 also had the lowest LEC value (0.18). Mean LER and LEC figures obtained were 1.33 and 0.43, respectively. Under row intercropping, competitive ratio values of sweet potato (CRPOT) were higher than 1.00, only in TIS 2532.OP.1.13 and TIS 87/0087. In strip-cropping, only TIS 2532.OP.1.13 gave a competitive ratio value of sweet potato above 1.00. Competitive ratio figures of pigeonpea (CRPPEA) were above unity when row – intercropped with all other sweet potato varieties, except TIS 2532.OP.1.13. Under strip – intercropping, only pigeonpea combined with 440293 had CRPPEA value higher than 1.00.Only row- intercropped TIS 87/0087 had CRPOT (1.13) and CRPPEA (1.14) at par, all other varieties had increased CRPOT with concomitant decreased CRPPEA and vice versa. In general, there was no significant difference between CRpot and CRPPEA (Table 5). ATER (Area x Time equivalent ratio) values were greater than 1.0 in row- and strip-intercropped TIS 86/0356, row-intercropped 199004-2 and strip-intercropped 440293; all other treatments gave ATER figures of less than 1.00.

Table 5 : Land equivalent ratio (LER), land equivalent coefficient (LEC), competitive ratio of sweet potato (CRPOT) and competitive ratio of pigeonpea (CRPPEA)of intercropped sweet potato with pigeonpea in Makurdi.

Treatment	LER	LEC	CRPOT	CRPPEA	ATER
TIS 87/0087 row - intercropped with pigeonpea	1.08	0.29	1.13	1.14	0.88
TIS 86/0356 row – intercropped with pigeonpea	1.74	0.66	2.19	0.52	1.44
TIS 2532.OP.1.13 row – intercropped with pigeonpea	0.97	0.22	0.61	3.19	0.86
440293 row – intercropped with pigeonpea	1.12	0.33	1.14	0.91	0.91
199004-2 row – intercropped with pigeonpea	1.97	0.75	2.80	0.38	1.45
Mean	1.38	0.45	1.57	1.23	1.10
TIS 87/0087 strip - intercropped with pigeonpea	1.24	0.39	0.73	0.35	0.99
TIS 86/0356 strip – intercropped with pigeonpea	1.36	0.45	0.77	0.33	1.19
TIS 2532.OP.1.13 strip – intercropped with pigeonpea	0.98	0.18	0.28	1.74	0.90
440293 strip – intercropped with pigeonpea	1.79	0.74	1.15	0.30	1.39
199004-2 strip – intercropped with pigeonpea	1.05	0.25	0.37	0.87	0.91
Mean	1.28	0.40	0.66	0.72	1.08
FLSD (0.05)	ns	ns	1.02	2.14	ns
Paired t-test (0.05) CRPOT vs CRPPEA			-0.32ns		

ns: not significant at 5% probability level

IV. Discussion

The rainfall received during the experimental periods of both 2009 and 2010 was considered adequate for crop growth and development. The non-significant effect of planting pattern on the fodder weight and number of saleable tubers per plant suggest that these traits might be under strong genetic control as opposed to planting environment. Anshebo *et al*. (2004) had reported that high heritability estimates were noticed for vine traits (length of vine, number of branches per plant and weight of foliage) of sweet potatoes in Madras, India. The higher number of branches per plant, tuber length and weight of sole cropped sweet potato as compared to intercropping (row- and strip- intercropping) can be attributed to greater availability of growth resources (light,water,soil nutrients,etc.) to sole crop plants than those intercropped with pigeonpea. Sharing of growth resources among components crops under intercropping can limit growth and accumulation of dry matter compared to sole cropping where competition exists (Dasbak and Asiegbu, 2009). Egbe and Idoko (2009) had observed depressive effects of pigeonpea on yields of sweet potato varieties at Otobi and associated such responses to decline of photosynthesis due to decreased solar radiation by shading of the sweet potato by the taller pigeonpea component. The superior performance of TIS 87/0087 (check) over all other varieties of sweet potato, except TIS 2532.OP.1.13, could imply that this variety was more suitable than the other varieties for cultivation with or without pigeonpea in Makurdi environment. Only this variety (TIS 87/0087) and TIS 2532.OP.1.13 had tuber yields above the mean yield (9.80 t/ha) of sweet potato in Benue State. TIS 2532.OP.1.13 should be cultivated in sole rather than intercropping for higher productivity. The orange flesh variety (440293) had about 25% of the current average yield of sweet potato in the State, making it difficult as a choice variety for adoption by farmers in the region. The reduction in the pod weight and grain yield of intercropped pigeonpea as compared with its sole might be ascribed to underground competition for soil growth resources (water and soil nutrients) between the intercrop components. It is known that competitive reactions reduce yields in intercropped crop species as compared to sole cropping (Egbe, 2005). TIS 87/0087 and the other varieties, except TIS 2532.OP.1.13, gave LER values above unity and LEC figures beyond 0.25, indicating intercrop advantages. These intercrop advantages may have arisen from the high yields of the pigeonpea component which made up for the reduction in the sweet potato yield. This may be a case typifying a "competition-recovery production principle" as proposed by Zhang and Li (2003), where after a dominant/base species is harvested, the subordinate/intercrop species has a recovery or complementary process so that the final yields remain unchanged or even increase compared with corresponding sole species. ATER values indicated yield advantages only for intercropped TIS 86/0356, 199004-2 and 440293. It showed that 19-39% hectare-days could be saved under strip intercropping and 44-45% under row intercropping. Strip intercropping of these three sweet potato varieties with pigeonpea could therefore be an alternative production system for sweet potato growers. Intercrop productivity measures (LER, LEC, CR, ATER) used in this study indicated poor performance of TIS 2532.OP.1.13, although it gave comparable saleable tuber yield with TIS 87/0087. This result was at variance with the findings of Njoku *et al.* (2007), who had identified TIS 2532.OP.1.13 to give remarkable yields when intercropped with okra in southeastern Nigeria. The high productivity indices of the orange flesh variety (440293), despite its low saleable tuber yield may be indicative of its ability to tolerate shading under intercropping with pigeonpea.

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