Pigeonpea / Sorghum Intercropping in Southern Guinea Savanna: Effects of Planting Density of Pigeonpea.

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Abstract: A field experiment was conducted for two years (2008-2009 and 2009-2010 cropping seasons) at the National Root Crops Research Institute Sub-station, Otobi and at the Teaching and Research Farm of the University of Agriculture, Makurdi in Benue State, all located in Southern Guinea Savanna of Nigeria. The experiment was undertaken to evaluate the effects of increased population densities of intercropped pigeonpea (*Cajanus cajan*) on its yield performance and that of the sorghum (*Sorghum bicolor*) component in Southern Guinea Savanna region of Nigeria with the aim of improving the productivity of this intercropping system. Intercropping decreased the number of pods per plant, dry pod weight and grain yield of the pigeonpea component as well as the panicle length, panicle weight and dry grain yield of the sorghum component. Pigeonpea canopy width, number of pods per plant, dry pod weight and grain yield decreased with increased density of pigeonpea in both sole and intercropped situations in both locations and in both years. A reverse trend was observed for length of the pod-bearing portion of pigeonpea. Pigeonpea proved more productive under intercropping than in sole systems as indicated by LER (1.31-1.33) and LEC (0.39-0.41) values. Intercropping pigeonpea at 33,000.00 plants/ha (P33) with sorghum produced higher number of seeds/plant, dry pod weight and grain yield of pigeonpea than at the other population densities tested. Similarly, the panicle length, panicle weight and grain yield of sorghum were higher when intercropped with P33 than at the other population densities tested .Competitive ratio (CR) values were lowest at P33,suggesting that both intra- and inter-specific competitions were least at this population density of pigeonpea. Pigeonpea equivalent yield values suggested that pigeonpea was more productive at Otobi than Makurdi, although this was not significant.
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Key words: intercropping, planting density, pigeonpea, sorghum, competition.

Introduction

Increasing interest in sustainability and environmental concerns has shifted attention back to intercropping as a means of better utilization of resources while preserving the environment (Anders *et al*., 1996). Advantages of intercropping are numerous and well-documented (Chatterjee and Mandal, 1992; Egbe *et al*.2009; Egbe, 2010). Pigeonpea is a crop of enormous potential in Southern Guinea Savanna environment of Nigeria (Egbe and Kalu,2006;Egbe and Adeyemo,2006) .Farmers in Southern Guinea Savanna of Nigeria intercrop pigeonpea with yams, cassava, maize, sorghum and in a few cases, millet (Egbe and Kalu,2006). Pigeonpea intercropping with the local red sorghum seem to be gaining some popularity in the region probably because of some reasonable yield obtained by the farmers even in marginal soil conditions in the absence of fertilizers and in years of low rainfall. Yields of up to 1.42 t/ha of intercropped pigeonpea (farmer's variety) and ›2.0 t/ha of local red sorghum have been obtained in experimental plots under farmer's condition (Egbe, 2005). Presently, pigeonpea farmers in Southern Guinea Savanna intercrop it at varying population densities (28,000-40,000 plants/ha) with sorghum, depending on location and the prevailing farming practices with attendant dismal yield figures of 0.35-0.52 t/ha of pigeonpea and 0.5-0.8 t/ha of sorghum (BNARDA, 2007; Egbe *et al*., 2009). Agronomic practices such as plant population is known to affect crop environment, which influence the yield and yield components. Optimum population levels should be maintained to exploit maximum natural resources, such as nutrient, sunlight, soil moisture and to ensure satisfactory yield (Sharifi *et al*., 2009). If plant population is lower than optimum then per hectare production will be low and weeds will also be more (Allard, 1999).The work reported here was undertaken to determine the effect of planting density of pigeonpea on its yield and yield components as well as its influence on the yield of the component sorghum. The work aimed at improving the productivity of the pigeonpea/sorghum intercropping systems with a view to increasing food security in the Southern Guinea Savanna agro-ecological zone of Nigeria.

Materials and Methods

A field experiment was conducted for two years (2008 and 2009) at the National Root Crops Research Institute Sub-station, Otobi [Latitude 07° 10 ′ N, Longitude 08° 39 ′ E, elevation 105.1 m] and at the Teaching and Research Farm of the University of Agriculture, Makurdi [Latitude 07^0 45′ - 07^0 50′ N, Longtitude 08^0 45′ - 08^0 50′ E,elevation 98 m] in Benue State, all located in Southern Guinea Savanna of Nigeria(Kowal and Knabe,1972). The experiment was undertaken to evaluate the effects of increased population densities of intercropped pigeonpea on its yield performance and that of the sorghum component in Southern Guinea Savanna region of Nigeria. The experimental sites received a total rainfall of 1133.5 mm and 1453.3 mm, respectively in 2008 and 1234.4 mm and 1543.6 mm, respectively in 2009. The soil at the experimental site in Makurdi was classified as Dystric Ustropept (USDA), while that at Otobi was classified as Typic Paleustalf (USDA). The same sites were used for the experiment in each year. Ten core samples of soil were collected from different parts of the experimental field and bulked into a composite sample and used for the determination of the chemical and physical properties of the soil before planting in each location. The physical and chemical properties of the soils in each of the locations are presented in Table 1.

The experiment was designed as randomized-complete block and laid out in split plot with three replications. The main plot treatment comprised of cropping systems with two levels (sole cropping, intercropping), while the sub-plot treatment was plant population density of pigeonpea at four levels [33,000 plants per hectare designated as **P33**;40,000 plants per hectare designated as **P40** ; 66,000 plants per hectare designated as **P66** and 100,000 plants per hectare designated as **P100**]. In the field, the four population densities of pigeonpea were established as follows:**P33**(1 m x 0.30 m x 1 plant/hill),**P40**(1 m x 0.25 m x 1 plant/hill), **P66**(1 m x 0.3 m x 2 plant/hill) and **P100** (1 m x 0.20 m x 2 plants/ hill). Gross plot size was 4 m x 3 m. The pigeonpea and sorghum seeds were sourced from the local market at Otobi. Pigeonpea *var.igbongbo* (sole as well as intercrop) was sown on the same day with sorghum (traditional, photoperiodic-sensitive, red-colored grain) during the last week of June of each experimental year. In both sole- and inter-cropped plots, sorghum population density was maintained at 40,000 plants per hectare (1 m x 0.5 m x 2 plants/hill). Intercropping had a 1:1 (pigeonpea: sorghum) row proportion. All plots received a basal application of 100 kg of NPK: 15:15:15 at the rate of 15 kg N, 6.45 kg P and 12.45 kg K per hectare by broadcasting. The sole- and inter –cropped sorghum were top-dressed four weeks after planting(w.a.p) with 46 kg N per hectare by opening the soil around each plant and banding at 5-8 cm depth and covering with the dug-out soil. Two manual weeding were done at 3 w.a.p. and 6 w.a.p., respectively. Harvesting of both crops was done from the inner 2 m x 2 m at physiological maturity and this represented yield per plot .Other parameters measured for pigeonpea at harvest included the following: canopy width (m), plant height (m),pod-bearing portion, number of pods per plant and dry pod weight (t/ha). The characters measured for the sorghum component were: dry grain yield (t/ha), panicle weight (t/ha) and panicle length (cm).

Intercrop advantage was calculated by the determination of land equivalent ratio (LER) (Ofori and Stern, 1987).The LER, an accurate assessment of the biological efficiency of the intercropping situation, was calculated as:

$$\textbf{LER} = (\textbf{\textit{Y}}ab/\textbf{\textit{Y}}aa) + (\textbf{\textit{Y}}ba/\textbf{Y}bb)$$

Where *Yaa* and *Ybb* are yields as sole crops of *a* and *b* and *Yab* and *Yba* are yields as intercrops of *a* and *b*. Values of LER greater than 1 are considered advantageous.

The relative dominance of one species over the other in this intercropping study was estimated by the use of relative crowding coefficient (K) (Banik *et al*., 2006). K was calculated as:

$$\mathbf{K} = (\mathbf{K}\textit{pigeonpea} \times \mathbf{K}\textit{sorghum})$$

$$\text{Where, } \mathbf{K}\textit{pigeonpea} = \mathbf{Y}ab \times \mathbf{Z}ba \,/\, (\mathbf{Y}aa - \mathbf{Y}ab) \times \mathbf{Z}ab$$

$$\mathbf{K}\textit{sorghyum} = \mathbf{Y}ba \times \mathbf{Z}ab \,/\, (\mathbf{Y}bb - \mathbf{Y}ba) \times \mathbf{Z}ba,$$

where, **Y***ab* and **Y***ba* were the yields of pigeonpea and sorghum in the intercrop, respectively, **Y***aa* and **Y***bb* ,were the yields of pigeonpea and sorghum in sole crop, respectively and **Z***ab* and **Z***ba* were the respective proportions of pigeonpea and sorghum in the in the intercropping systems. When the value of K is greater than 1.00, there is intercrop advantage; when K is equal to 1.00, there is no yield advantage; and when K is less than 1.00, there is a disadvantage.

Land equivalent coefficient (LEC), a measure of interaction concerned with the strength of relationship was calculated thus,

LEC = **L***a* x **L***b*

Where,**L***a* = LER of main crop and **L***b* = LER of intercrop (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.

Competitive ratio (CR) indicates the number of times by which one component crop is more competitive than the other. Relative species competition is often evaluated using competitive ratios (Putnam *et al*., 1984).This was calculated as:

R*a* = **L***a*/**L***b* 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*ab* 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 R*a* > 1, there a negative benefit. The reverse is true for R*b.*

Pigeonpea yield equivalent was calculated as described by Prasad and Srivastava (1991).

Pigeonpea equivalent (t/ha)

= *Yield of intercrop/Market price of pigeonpea x Market price of intercrop*

Standard procedures were followed to collect data and analyzed using GENSTAT Release 7.23 (2007), following standard analysis of variance procedures and least significant difference (LSD) test at 5% probability level was used to compare the treatment means. Location and year means were compared using paired t-test at 5% probability level.

Results

Cropping systems x density interaction effects on the pigeonpea canopy width, pod-bearing portion, number of pods per plant, dry pod weight and dry grain yield were not significant (P≥ 0.05), but it was significant for plant height of pigeonpea intercropped with sorghum in both Makurdi and Otobi in 2009 only. The main effect of density on these plant characteristics of pigeonpea intercropped with sorghum were consistently significant (P≤0.05), while the main effect of cropping systems was erratic.

Table 2 presents the results of the cropping systems with density interaction effects on the plant height of pigeonpea intercropped with sorghum in Makurdi and Otobi in 2008 and 2009.In both cropping systems, pigeonpea produced shorter plants at P100 than at any of the other populations tested in both locations. In Makurdi environment, intercropping significantly depressed plant height of pigeonpea, irrespective of the plant population adopted in 2009, but not so at Otobi, where a similar trend was observed only in 2008. Pigeonpea plant height in Makurdi did not differ significantly from that at Otobi, neither did it differ from year to year. The plant height of pigeonpea ranged from 3.01 m - 3.55 m in sole systems in Makurdi and varied from 2.60 m – 2.91 m at Otobi. Under intercropping pigeonpea produced plants that were 2.77 – 3.43 m tall in Makurdi, but it was 2.71 m – 2.82 m tall at Otobi. Plant height of pigeonpea also decreased with its increasing population in both sole and intercropped situations.

Table 3 shows the results of the main effect of density on the canopy width of pigeonpea intercropped with sorghum in Makurdi and Otobi in 2008 and 2009. In both locations of the experiment, canopy width decreased with increasing population of pigeonpea in both 2008 and 2009.Canopy width of pigeonpea in Makurdi was not significantly different from that at Otobi, neither did it differ in 2008 from that of 2009. Length of pod-bearing portion of pigeonpea intercropped with sorghum increased with increase in pigeonpea planting density in the two locations and in both of the experimental years (Table4). It varied from 75.20 cm to 80.58 cm in Makurdi, and 79.39 - 81.19 cm at Otobi. **P100** consistently produced the highest pod-bearing portion of stem with a mean of 80.58 cm in Makurdi and 86.04 at Otobi. **P33** gave the lowest pod-bearing portion of stem in both locations {Makurdi (75.20 cm) and Otobi (79.39 cm)}.There were hardly any significant differences in pod-bearing portion of stem of pigeonpea between **P33,P40** and **P66**.

Cropping systems x density interaction effects on the number of pods/plant and pod weight of pigeonpea intercropped with sorghum in Makurdi and Otobi in 2008 and 2009 were not significant (P≥0.05),but the main effects of cropping systems and density were significant (P≤0.05) (Table 5). Intercropping reduced the number of pods/plant of pigeonpea,irrespective of the density adopted in both locations and in both years. Pods/plant of pigeonpea varied from 201.40 to 291.85 under sole systems in Makurdi and 118.60-246.40 at Otobi,while it varied from 157.30-273.20 under intercropping in Makurdi and 89.35-214.30 at Otobi. Pods/plant of pigeonpea decreased with planting density. Pigeonpea at **P33** consistently gave the hjghest pods/plant,while **P100** produced the least pods/plant in both years and in both locations.There was no significant difference between number of pods/plant of pigeonpea in Makurdi and that in Otobi, neither was the year effect significant. Intercropping significantly decreased dry pod weight of pigeonpea in all locations and in both years, except in Otobi in 2009, where the decrease was not significant. In Makurdi, mean dry pod weight of pigeonpea for the two years varied from 1.72 t/ha to 2.61 t/ha in sole cropping, while it was 2.55-4.34 t/ha in Otobi . Under intercropping, pigeonpea dry pod weight varied from 1.43-2.33 t/ha in Makurdi for both years and 2.68-3.88 t/ha at Otobi. However, the dry pod yield of pigeonpea was significantly higher at Otobi than Makurdi in both cropping systems. Dry pod weight of sole pigeonpea averaged 3.56 t/ha in Otobi as compared to 2.17 t/ha in Makurdi. Similarly, intercropped pigeonpea gave a mean pod yield of 3.27 t/ha at Otobi, while it was only 1.81 t/ha in Makurdi. Dry pod weight of pigeonpea was significantly higher in 2009 than in 2008.Generally, dry pod weight of pigeonpea decreased with increase in plant population density from **P33** to **P100** in both cropping systems. The trend was similar for both locations and in both years. **P33** consistently gave the highest pod weight, while **P100** produced the lowest pod weight.

Intercropping decreased the grain yield of pigeonpea in both locations and in both years (Table 6). Grain yield of pigeonpea varied from 0.88-1.17 t/ha in Makurdi in sole systems and 0.63-0.85 t/ha under intercropping in the same location. In Otobi the dry grain yield of pigeonpea ranged from 1.09-1.69 t/ha in sole cropping and 0.97-1.31 t/ha in intercropping systems (Table 6).The dry grain yield of pigeonpea generally declined with increase in density from **P33** to **P100** (Table 6).The trend was similar in both locations and in both years, except in 2008 at Otobi, where no significant effect of density was observed in yield between the various planting population densities of pigeonpea. Grain yields were usually highest at **P33**, although this was not significantly different from the yield at **P40**.**P100** consistently produced the lowest grain yield in all locations in both years, except, at Otobi in 2008.where the yield was only higher than pigeonpea at **P66**.

Table 7 presents the results of the panicle length and weight of sorghum intercropped with pigeonpea in Makurdi and Otobi in 2008 and 2009. Sole sorghum gave significantly higher panicle length and weight than intercropped sorghum at the various densities in both locations and both years. Under intercropping, however, sorghum panicle length and weight were consistently higher at **P33** than at the other densities tested. Sorghum at **P100** produced the least panicle length and weight in Makurdi and Otobi in both experimental years, except at Otobi in 2008. Location and year effects were not significant for both panicle length and weight.

Table 8 indicates the results of the grain yield of sorghum intercropped with various densities of pigeonpea in Makurdi and Otobi in 2008 and 2009. Intercropping reduced the dry grain yield of sorghum at the various densities of pigeonpea when compared to its yield in sole cropping. The mean yield of intercropped sorghum in Makurdi was 0.55 t/ha and 0.96 t/ha at Otobi. The mean sole sorghum yield in Makurdi environment was 0.95 t/ha for both years and 2.02 t/ha at Otobi. The yield of intercropped sorghum decreased with increasing density of pigeonpea in both locations and in both years. Sorghum in **P33** generally gave the highest grain yield, while that planted in **P100** gave the lowest yield in each of the locations. Location and year effects were not significant.

LER values of pigeonpea intercropped with sorghum at both Makurdi and Otobi were above 1.00 at all planting densities in both years, except in Makurdi in 2009 (Table 9). LER figures were highest at **P33** in both locations and both years, but this was only significantly different from the other population densities in 2009 in both locations.

LEC figures of pigeonpea intercropped with sorghum were all above 0.25 in Makurdi and Otobi at all densities in 2008 and 2009, except in Makurdi at **P100** (0.22) in 2009 and at **P40** (0.19) in Otobi in 2008.LEC values were consistently highest at **P33** in both locations and in both years, but the trends were inconsistent at the other population densities (Table 9). Significant differences in LEC figures were only recorded in 2009 and in both locations. Neither location nor year effects were significant for LER and LEC (Table 9).

K values were less than 1.00 at almost all densities in both locations and years, except at **P40** (1.39) in Makurdi in 2008 and at **P66** and **P100** (2.06 and 1.09, respectively) in Otobi in 2008 and at **P33** and **P40** (1.62 and 1.51, respectively) in 2009 (Table 10).

CR values increased with increase in density from **P33** to **P100** in each of the experimental locations and years (Table 10). Pigeonpea at **P100** gave the highest CR figures in both locations and years, except at Otobi in 2009, where the CR values at **P100** and **P66** were the same (2.36). P33 produced the lowest CR values compared to the other densities in both the locations and years of experimentation.

Figures 1&2 present equivalent grain yields of pigeonpea intercropped with sorghum in Makurdi and Otobi in 2008 and 2009.Pigeonpea intercropped with sorghum at Otobi consistently produced higher grain equivalent yields than pigeonpea in Makurdi, irrespective of the planting density, except at **P100** in 2009, where the pigeonpea equivalent yields were the same (0.21 t/ha).

Table 1: Physical and chemical properties of the surface soil (0-30 cm) at the experimental sites in Makurdi and Otobi in 2008 and 2009.

	Makudi		Otobi	
Parameter	2008	2009	2008	2009
Sand (%)	80.00	74.60	71.40	66.40
Silt (%)	16.20	20.20	12.20	14.10
Clay (%)	3.20	5.20	16.40	19.50
Textural class	Sandy loam	Sandy loam	Sandy loam	Sandy loam
pH (H2O)	6.20	6.40	6.34	6.74
Organic carbon (%)	0.51	0.63	0.67	0.75
Organic matter (%)	0.88	0.99	1.20	1.38
Total N (%)	0.08	0.11	0.11	0.16
Available P (cmol kg-1 soil)	4.60	4.88	16.70	17.44
Ca2+ (cmol kg-1 soil)	3.00	3.55	4.33	4.88
Mg2+ (cmol kg-1 soil)	1.17	2.13	3.89	3.91
K+ (cmol kg-1 soil)	0.20	0.34	11.17	13.66
Na+ (cmol kg-1 soil)	0.21	0.19	2.90	2.22
Exch.acidity (cmol kg-1 soil)	0.29	0.32	0.34	0.41
ECEC (cmol kg-1 soil)	4.87	6.53	16.63	17.08

Table 2: Influence of cropping systems with density on the plant height of (m) of pigeonpea intercropped with sorghum in Makurdi and Otobi in 2008 and 2009.

		Plant height					
		Makurdi			Otobi		
Cropping systems(CS)	Density(DEN)	2008	2009	Mean	2008	2009	Mean
Sole crop:	P33	3.48	3.63	3.55	2.96	2.87	2.91
	P40	3.45	3.54	3.49	2.92	2.75	2.83
	P66	3.23	3.45	3.34	2.85	2.63	2.74
	P100	2.95	3.07	3.01	2.74	2.47	2.60
	Mean	3.28	3.67	3.47	2.87	2.68	2.77
Intercrop:							
	P33	3.46	3.41	3.43	2.78	2.86	2.82
	P40	3.29	3.24	3.26	2.82	2.67	2.74
	P66	3.11	3.00	3.05	2.70	2.72	2.71
	P100	2.96	2.59	2.77	2.65	2.45	2.55
	Mean	3.20	3.06	3.13	2.74	2.67	2.70
FLSD(0.05)	CS	ns	0.05		0.07	ns	
	DEN	0.13	0.08		0.10	0.06	
	CS X DEN	ns	0.11		ns	0.08	
Paired t-test(0.05)							
Makurdi vs Otobi	2.89ns						
2008 vs 2009	0.99ns						

Table 3: Canopy width (cm) of intercropped pigeonpea with sorghum as influenced by density in Makurdi and Otobi in 2008 and 2009.

Density	Canopy width					
	Makurdi			Otobi		
	2008	2009	Mean	2008	2009	Mean
P33	143.70	139.00	141.35	140.10	145.17	142.35
P40	134.70	134.65	134.68	138.10	142.07	140.09
P66	138.20	128.32	133.26	130.40	139.25	134.83
P100	118.50	119.62	119.20	114.30	128.25	121.25
Mean	133.78	130.98	132.38	130.73	109.84	120.29
FLSD (0.05)	19.44	4.44		6.09	3.27	
Paired t-test (0.05)						
Makurdi vs Otobi	1.34ns					
2008 vs 2009	1.12ns					

Table 4: Length of pod-bearing portion (cm) of pigeonpea intercropped with sorghum as affected by planting density in Makurdi and Otobi in 2008 and 2009.

Density	Length of pod-bearing portion of pigeonpea					
	Makurdi			Otobi		
	2008	2009	Mean	2008	2009	Mean
P33	74.70	75.72	75.20	82.77	76.00	79.39
P40	79.30	76.67	77.99	82.48	76.83	79.66
P66	80.30	81.43	80.87	85.65	76.72	81.19
P100	94.30	82.20	88.25	91.00	81.07	86.04
Mean	82.15	79.01	80.58	85.48	77.66	81.57
FLSD (0.05)	7.22	5.53		5.59	3.82	
Paired t-test (0.05)						
Makurdi vs Otobi	-0.42ns					
2008 vs 2009	1.30ns					

Table 5: Cropping systems (CS) with density (DEN) effects on the number of pods per plant and dry pod weight (t/ha) of pigeonpea intercropped with sorghum in Makurdi and Otobi in 2008 and 2009.

	Pods/plant						Pod weight					
	Makurdi			Otobi			Makurdi			Otobi		
CS/DEN	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
Sole crop:												
P33	284.20	299.50	291.85	111.30	381.50	246.40	2.32	2.90	2.61	3.67	5.01	4.34
P40	259.70	257.10	258.40	78.30	353.10	215.70	1.98	2.76	2.37	3.68	4.45	4.06
P66	228.40	236.50	232.45	96.70	279.70	188.20	1.57	2.44	2.00	3.07	3.55	3.31
P100	268.40	134.40	201.40	58.80	178.40	118.60	1.45	2.00	1.72	3.40	1.70	2.55
Mean	260.18	229.38	244.78	86.28	298.18	192.23	1.83	2.52	2.17	3.45	3.68	3.56
Intercrop:												
P33	267.40	279.00	273.20	112.30	316.30	214.30	1.97	2.69	2.33	3.58	4.18	3.88
P40	256.60	248.40	252.50	55.90	264.30	160.10	1.57	2.21	1.89	2.68	4.12	3.40
P66	213.20	202.70	207.95	68.90	230.90	149.90	1.14	2.09	1.61	2.48	3.74	3.11
P100	189.30	125.30	157.30	48.40	130.30	89.35	1.26	1.60	1.43	3.25	2.12	2.68
Mean	231.63	213.85	222.74	71.38	235.45	153.42	1.48	2.15	1.81	3.00	3.54	3.27
FLSD (0.05)												
CS	24.84	12.64		10.87	17.74		0.24	0.32		0.45	ns	
DEN	35.12	17.88		15.38	25.09		0.34	0.45		0.64	0.66	
CS X DEN	ns	ns		ns	ns		ns	ns		ns	ns	
Paired t-test (0.05)												
Makurdi vs Otobi	7.27ns									-40.71*		
2008 vs 2009	-1.57ns									-4.29*		

Table 6: Grain yield (t/ha) of pigeonpea as influenced by cropping systems(CS) with density (DEN) in Makurdi and Otobi in 2008 and 2009.

	Grain yield					
	Makurdi			Otobi		
CS/DEN	2008	2009	Mean	2008	2009	Mean
Sole crop:						
P33	1.18	1.16	1.17	1.49	1.90	1.69
P40	1.07	1.24	1.15	1.48	1.80	1.64
P66	0.82	1.09	0.95	1.14	1.61	1.37
P100	0.71	1.06	0.88	1.42	0.77	1.09
Mean	0.94	1.14	1.04	1.38	1.52	1.45
Intercrop:						
P33	0.86	0.85	0.85	1.04	1.58	1.31
P40	0.84	0.74	0.79	0.86	1.64	1.26
P66	0.64	0.71	0.67	0.98	1.52	1.25
P100	0.54	0.63	0.58	1.32	0.63	0.97
Mean	0.72	0.73	0.72	1.05	1.34	1.20
FLSD (0.05)						
CS	0.09	0.06		0.16	0.10	
DEN	0.13	0.08		ns	0.14	
CS X DEN	ns	ns		ns	ns	
Paired t-test (0.05)						
Makurdi vs Otobi	-12.71*					
2008 vs 2009	-1.57ns					

Table 7: Panicle length (cm) and weight (t/ha) of sorghum intercropped with pigeonpea in Makurdi and Otobi in 2008 and 2009.

CS	Panicle length						Panicle weight					
	Makurdi			Otobi			Makurdi			Otobi		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
Sole crop:	46.20	45.73	45.96	53.20	49.67	51.43	2.94	2.90	2.92	5.16	4.30	4.73
Intercrop:												
Sorghum in P33	44.77	40.87	42.82	47.00	44.37	45.68	2.72	2.61	2.66	3.55	3.71	3.63
Sorghum in P40	41.98	38.77	40.37	43.00	42.70	42.85	2.56	2.03	2.30	2.14	3.16	2.65
Sorghum in P66	43.07	38.17	40.62	44.40	40.12	42.26	2.18	1.43	1.80	3.04	2.29	2.66
Sorghum in 100	40.50	35.77	38.13	38.60	38.13	38.36	1.95	0.78	1.36	2.20	1.78	2.00
Mean of intercropping	42.58	38.39	40.48	43.25	41.33	42.28	2.35	1.71	2.03	2.73	2.73	2.93
FLSD (0.05)	2.08	4.73		7.30	4.32		0.39	0.31		1.41	0.50	
Paired t-test (0.05)												
Makurdi vs Otobi	-1.92ns						-2.26ns					
2008 vs 2009	1.11ns						-0.17ns					

Table 8: Dry grain yield (t/ha) of sorghum as affected by intercropping with pigeonpea in Makurdi and Otobi in 2008 and 2009.

Cropping systems	Dry grain yield					
	Makurdi			Otobi		
	2008	2009	Mean	2008	2009	Mean
Sole cropping	1.06	0.85	0.95	3.10	0.95	2.02
Intercropping						
Sorghum in P33	0.77	0.74	0.75	1.99	0.72	1.35
Sorghum in P40	0.79	0.45	0.62	1.35	0.52	0.93
Sorghum in P66	0.65	0.38	0.51	1.35	0.47	0.91
Sorghum in 100	0.38	0.31	0.34	0.98	0.36	0.67
Mean of intercropping	0.64	0.47	0.55	1.42	0.51	0.96
FLSD (0.05)	0.25	0.12		0.80	0.20	
Paired t-test (0.05)						
Makurdi vs Otobi	-2.24ns					
2008 vs 2009	0.37ns					

ns: not significant at 5% probability level.

Table 9: Effect of planting density on the land equivalent ratio (LER) and land equivalent coefficient (LEC) of pigeonpea intercropped with sorghum in Makurdi and Otobi in 2008 and 2009.

Density	LER						LEC					
	Makurdi			Otobi			Makurdi			Otobi		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
P33	1.49	1.46	1.48	1.36	1.57	1.47	0.57	0.54	0.56	0.43	0.65	0.54
P40	1.55	1.12	1.34	1.04	1.42	1.23	0.60	0.32	0.46	0.19	0.51	0.35
P66	1.42	1.09	1.26	1.31	1.49	1.40	0.50	0.29	0.40	0.38	0.49	0.44
P100	1.39	0.96	1.18	1.25	1.21	1.23	0.91	0.22	0.57	0.30	0.31	0.31
Mean	1.46	1.16	1.31	1.24	1.42	1.33	0.44	0.34	0.39	0.33	0.49	0.41
FLSD (0.05)	ns	0.34		ns	0.14		ns	0.21		ns	0.09	
Paired t-test (0.05)												
Makurdi vs Otobi	-0.08ns						-0.15ns					
2008 vs 2009	-0.77ns						-1.06ns					

Table 10: Influence of density of intercropped pigeonpea with sorghum on relative crowding coefficient (K) and competitive ratio (CR) values in Makurdi and Otobi in 2008 and 2009.

Density	K						CR					
	Makurdi			Otobi			Makurdi			Otobi		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
P33	-0.16	0.02	-0.07	-0.35	1.62	1.10	1.30	1.26	1.28	1.55	1.37	1.46
P40	1.39	0.33	0.86	0.53	1.51	1.02	1.30	1.37	1.34	1.68	1.94	1.81
P66	0.66	0.39	0.53	2.06	0.43	0.82	1.60	1.78	1.69	2.45	2.36	2.41
P100	0.06	0.26	0.16	1.09	1.02	0.55	10.00	2.00	6.00	3.62	2.36	2.99
Mean	0.53	0.34	0.45	0.95	0.93	0.94	3.55	1.60	2.58	2.33	2.01	2.17
FLSD (0.05)	ns	ns		ns	ns		ns	0.42		1.21	ns	
Paired t-test (0.05)												
Makurdi vs Otobi	-5.94ns							0.50ns				
2008 vs 2009	-0.71ns							0.50ns				

Figure 1:Grain yield equivalent of pigeonpea (t/ha) intercropped with sorghum in Makurdi and Otobi as affected by density of pigeonpea in 2008.

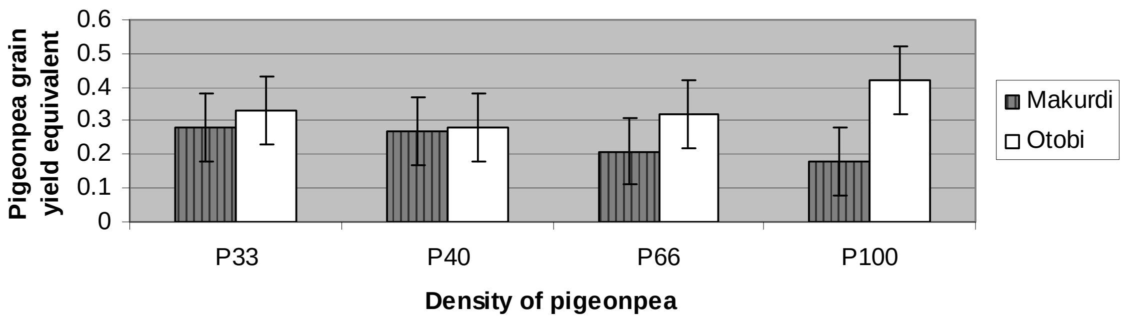
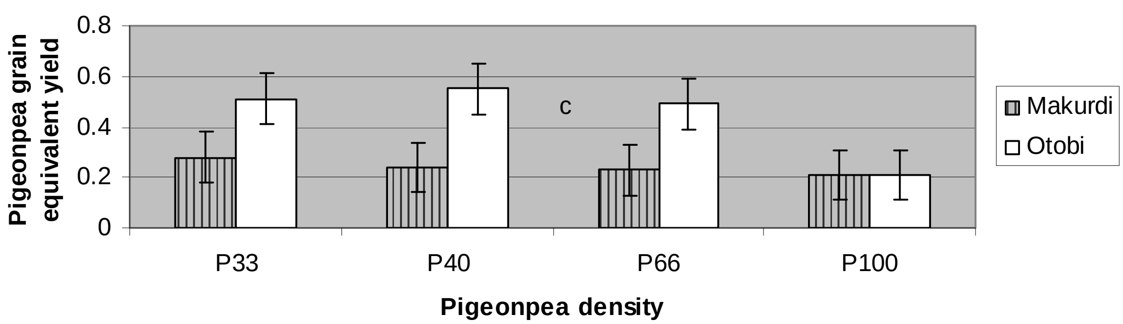


Figure 2:Grain yield equivalent (t/ha) of pigeonpea intercropped with sorghum in Makurdi and Otobi as affected by planting density of pigeonpea in 2009.



Discussion

The decreases observed in plant height and canopy width with increased population density of pigeonpea in both sole and intercropped situations might be ascribed to intensification of interplant competition for growth factors (light, water and soil nutrients).Sharifi *et al.*(2009) had noted that when plant population is too high, it encourages inter plant competition for resources ,and consequently, the net photosynthesis would be affected due to less light penetration in the crop canopy as well as increase in the competition for available nutrient resulting in poor growth of the plants. In addition, a plant population density resulting in interplant competition affects vegetative and reproductive growth (Zhang *et al.*, 2006).The increased length of pod-bearing portion of pigeonpea with increase in planting density might be a response usually described as morphological plasticity. Lyon (2009) had described morphological plasticity as the plant's capacity to change its form in response to varying environmental conditions. Egbe (2005) had observed a similar behavior of pigeonpea varieties intercropped with sorghum at Otobi. The reduction of the number of pods/plant, dry pod weight and dry grain yield of pigeonpea with increased plant density in both sole and intercropped environments observed in this study might be due to interplant competition as earlier noticed in the plant height and canopy width of the crop. These findings might justify the present population densities presently being used by pigeonpea farmers in the region, especially when planting the traditional variety (*'igbongbo'*).These results may also indicate that some other management factors different from plant population might be responsible for the low yield of pigeonpea on farmers' fields-a need for further research. Such findings have implications for incorporation of indigenous knowledge in research designs to tackle farmers' problems. The decline in the number of pods per plant, dry pod weight and grain yield of intercropped pigeonpea as compared to its sole cropping might also have resulted from inter- and intra- specific competition for plant growth resources. The taller sorghum component of the intercropping might have exerted depressive effects through shading of the shorter and slower growing pigeonpea component. Dasbak and Asiegbu (2009) and Egbe and Adeyemo (2006) had made similar observations in pigeonpea/maize intercropping and attributed such responses to negative effects of the intercropped cereal crop on the pigeonpea component. Dasbak and Asiegbu further stated that sharing of growth resources among component crops under intercropping also limited growth and accumulation of dry matter compared to sole cropping where such competition existed. Competition between component crops for growth-limiting factors is regulated by morphophysiological differences and agronomic factors such as the proportion of crops in the mixture and fertilizer application (Trenbath, 1976; Russell & Caldwell, 1989). The superior performance of sole sorghum compared to its intercropping might be associated with the complete absence of interspecies competition in the sole system and the presence of both inter- and intra- specific competition in intercropping. Egbe (2005) had recorded similar findings in his work on evaluating agronomic potentials of 15 pigeonpea genotypes under intercropping with maize and sorghum in Southern Guinea Savanna of Nigeria. The decreases observed in panicle length, weight and grain yield of intercropped sorghum with increased density of pigeonpea might be due to increased underground competition from the pigeonpea component for mineral nutrients and water. The results of the intercropping indicated that the mean LER values were above unity in nearly all cases and that of LEC was consistently above 0.25 at all densities ,except at P100 in Makurdi in 2009 and at P40 in Otobi in 2008.These results showed complementarity in resource utilization by the intercrop component crops .Other studies (Dasbak and Asiegbu,2009, Egbe and Kalu,2009;Egbe,2010; Muoneke *et al*.,2007) had reported higher land productivity in pigeonpea/sorghum intercropping and other systems. The K values were inconsistent but CR values increased with increased planting density of pigeonpea under intercropping. According to Willey and Rao(1980),competitive ratio(CR) gives a better measure of competitive ability of crops and can prove a better index as compared to other indices of measuring intercrop competition. The increased CR values obtained in this study indicated intensification of competition with increased planting density .The results suggested that pigeonpea became more competitive than sorghum as its population under intercropping increased, leading to reduction of both sorghum and pigeonpea yields. Zhang (2006) had stated that the efficiency of conversion of intercepted solar radiation in maize decreases with a high plant population density because of mutual shading in the plants, leading to decreased yields at high population densities. The decreased yields of pigeonpea in sole systems with increases in planting density might be explained by the same phenomenon. The superior performance of both intercrop components at **P33** suggested that competition for both above-ground and below-ground were lowest at this planting density, suggesting that that pigeonpea var. '*igbongbo* 'would be more productive at this density when intercropped with sorghum. The high CR figures for pigeonpea in this study might indicate its superior competitive ability underground when compared to sorghum and this ability seemed to increase with increases in planting density. Ito *et al*. (1993) had reported and suggested that pigeonpea roots were physiologically more active than sorghum roots, implying that pigeonpea might become a strong competitor for nutrients in the soil when intercropped. The higher pigeonpea equivalent yields in Otobi than Makurdi might be attributed to more favorable environmental conditions for pigeonpea production (rainfall,soil.etc.) present in Otobi than at Makurdi, an indication that pigeonpea was more at home in Otobi than in Makurdi. Pigeonpea is more widely grown in Otobi than in Makurdi (BNARDA,2007,Egbe,2005).

Conclusion:

Pigeonpea proved more productive under intercropping than in sole systems as indicated by LER (1.31-1.33) and LEC (0.39-0.41) values. Intercropping pigeonpea at 33,000.00 plants/ha (**P33**) with sorghum produced higher number of seeds/plant, dry pod weight and grain yield of pigeonpea. Similarly, the panicle length, panicle weight and grain yield of sorghum was higher when intercropped with **P33** pigeonpea than at the other population densities tested .Competitive ratio (CR) values were lowest at **P33**,suggesting that both intra- and inter-specific competitions were least at this population density. Pigeonpea equivalent yield values suggested that pigeonpea was more productive at Otobi than Makurdi, although this was not significant.

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