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ASSESSMENT OF BIOLOGICAL NITROGEN FIXING POTENTIALS OF PIGEONPEA GENOTYPES INTERCROPPED WITH SORGHUM FOR SOIL FERTILITY IMPROVEMENT IN SOUTHERN GUINEA SAVANNA OF NIGERIA.

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ABSTRACT

In a 2-year field/laboratory study, the biological nitrogen fixing potentials of 14 newly introduced pigeonpea (Cajanus cajan (L.) Millsp.) genotypes from ICRISAT along with a local check were assessed under intercropping with sorghum (Sorghum bicolour (L.) Moench.) in Southern Guinea Savanna of Nigeria. Using sorghum as the non-fixing control and N-difference method, estimates of fixed N in pigeonpea genotypes of different maturity ratings ranged from 37.52kg/ha to 164.82kg/ha under intercropping. The average total nitrogen concentration of shoot in intercropped pigeonpea genotypes at harvest (2.83%) was higher than that for intercropped sorghum (1.83%). There were very little differences between sole cropping and intercropping in total soil N for each of the crops in the intercrop combinations in both years.

Key words: biological nitrogen fixation, intercropping, pigeonpea, genotypes, sorghum.

INTRODUCTION

In the tropics, nitrogen is the most important nutrient required by plants and it is often the most limiting (Kaleem, 2000). Biological nitrogen fixation (BNF) is important in legume-based cropping systems when fertilizer nitrogen is limiting. A combination of legumes and cereals is popular, mainly due to the economic value of the legumes and the expectation of sustaining the soil fertility (especially nitrogen) over years (Ofori and Stern, 1987; Kumar Rao *et al.*, 1996). The inclusion of pigeonpea in intercropping systems helps to minimize competition for nitrogen with the cereal component (Adu-Gyamfi *et al.*, 1997) because pigeonpea is able to meet a proportion of its own N requirement through BNF (Kumar Rao *et al.* 1987) and also improve the soil organic matter status of the systems.

Kumar Rao *et al.* (1987) estimated that between 68-88kg of symbiotically fixed N was derived from pigeonpea in India depending on the season. Using sorghum as the non-fixing control and N-difference method, estimates of fixed N in pigeonpea genotypes of different maturity ranged between 6-69kg N per ha (Kumar Rao and Dart, 1987). Adu-Gyamfi *et al*. (1997) reported that the amount of N fixed by pigeonpea estimated by the ^{15}N natural- abundance method, during the entire growth period of 210 days, was 120-170kg N per ha The amount was higher in intercrop than .sole-cropped pigeon pea (Katayama *et al*., 1995; Tobita *et al*., 1994).

Quantification of the amount of nitrogen fixed by the newly introduced pigeon pea genotypes under intercropping with sorghum in Southern Guinea Savannah of Nigeria was undertaken to assess their N contributions to the system and their role in the improvement of farm productivity. Quantitative data on such are meagre or, in most cases, lacking in literature.

MATERIALS AND METHODS

Field experiments were conducted each year during the wet seasons of 2002 and 2003 at National Root Crops Research Institute sub-station, Otobi (07^0 10′N 08^0 39′E elevation 105.1m) in Benue State located in the Southern Guinea Savanna ecological zone of Nigeria (Kowal and Knabe, 1972). Rainfall at the site was 1712.00mm between June and November in 2002 and 1665.60mm within the same period in 2003. A pre-plant soil sample was taken to the depth of 0-30cm and characterised as sandy-loam with a pH of 7.60 in water. Organic carbon was 2.23%, total nitrogen, 0.71%, available phosphorus (Bray 1) 36ppm, and potassium 0.14%, CEC, 31.80meq/100 g in 2002. In 2003, a pre-plant soil sample analysis also characterised the soil as sandy loam with pH in water, 7.20, organic carbon 2.3%, total nitrogen, 1.04%, available phosphorus (Bray1) 72ppm,and potassium, 0.17%, CEC, 40.40meq/100g of soil. The experiment was a 3 x 15 factorial set out in a split plot design with three replications. The main plot treatment consisted of two sole cropping systems (pigeon pea or sorghum) and one intercropping (pigeon pea + sorghum). The sub-plot treatments were 15 pigeon pea genotypes, including a local check, namely: - ICPL 85010, ICPL 84031, ICPL 87, ICPL 161 (short duration), ICPL 8863, ICPL 85063, ICPL 87119, ICPL 7120, ICEAP 00068 (medium duration), ICPL 7035, ICPL 8094, ICPL 87051, ICPL 9145, ICEAP 00040 (long duration) and *Igbongbo*. The sorghum variety was the tall (4m or more) photoperiod–sensitive red sorghum popularly used by the local farmers. The use of the sorghum as the non-fixing plant was borne out of its popularity among the farmers in this region. The gross plot size was 3.0m x 4.0m while the net plot measured 2m x 2m. The pigeon pea genotypes and sorghum were sown as sole or intercrops on ridges spaced 1m apart. The optimum plant population densities for the respective sole crops of pigeon pea and sorghum were 66,666 and 40,000 per ha. The replacement series method of mixture was adopted. The agronomic parameters measured on pigeonpea genotypes were: number of nodules per plant, nodule biomass per plant, leaf litter at harvest and shoot dry matter yield. Soil tests were done in each of the years of experimentation. Soil samples were taken at 0-30cm depths from each treatment plot, air-dried and ground to pass through a 0.3mm screen for chemical analysis. Nitrogen in soil was estimated by indophenols colour formation method (Chaykin, 1969) after micro-Kjeldhal digestion. At harvest, oven-dried plant parts (pigeon pea – leaves, stems, roots, fallen parts, nodules and pod with seed) were ground to pass through a 0.3mm screen and used for chemical analysis. Nitrogen concentration in plant parts as estimated by the indophenol colour formation method (Chaykin, 1969) after micro-Kjeldhal digestion was determined. Similarly, oven-dried shoot samples of intercropped pigeonpea and sorghum were separately ground to pass through a 0.6mm screen for chemical analysis. Nitrogen yield in shoot samples was determined as outlined by Chaykin (1969) after micro-Kjeldhal digestion.

All the laboratory chemical analyses for total nitrogen, pH, organic carbon, and CEC were done in the Biochemistry and Applied Molecular Biology Department of the National Vertinerary Institute, Vom, Nigeria, while available phosphorus and potassium were determined at the Chemical and Physical Laboratories of Nigeria Mining Corporation, Jos, Nigeria.

Estimation of N –fixation: Estimation of nitrogen fixation in the cropping systems was determined by the N-difference method using the formula outlined by Papastytianou (1999) for estimation of the apparent net amount of atmospheric N_2 fixed by legumes in short- and long-term cropping systems:

$$N_2 = (L-M) + (fi - fm)$$

Where N_2 = amount of nitrogen fixed by system;

L = N harvested in a N_2 – fixing legume

M = the amount of N harvested in a non-N_2– fixing crop grown under the same condition as the legume;

fi = soil N after the legume

fm = soil N under the non-N_2– fixing crop.

This equation assumes that the legume and the non-legume crop absorbed the same amount of soil N. The soil N value (fi-fm) in the equation could be positive, zero or negative, depending on whether the legume system removed less, equal or more soil N than the non-legume grown in monoculture. The amount of total N fixed per ha for each pigeon pea genotype was obtained by multiplying the proportion of N derived from N fixation (**P**) by the dry shoot weight of each genotype per ha in the intercrop system. All data generated were analysed using GENSTAT Release 3.2 (Copyright 1995, Lawes Agricultural Trust Rothamsted Experimental Station). Statistical tests or mean differences and treatment effects followed standard analysis of variance procedures for a split plot `design (Gomez and Gomez, 1984). Wherever differences between treatment means were significant, mean separation was by F-LSD at 5% probability (Obi, 1986).

Table 1: Number of nodules per plant of pigeonpea genotypes as affected by intercropping with sorghum

		Cropping System					
		2002			2003		
Pigeonpea	Genotypes	Sole crop	Inter Crop	Mean	Sole crop	Inter Crop	Mean
ICPL	85010	128.17	50.00	89.09	81.83	84.00	82.92
ICPL	84031	119.00	40.50	79.75	107.50	123.17	169.09
ICPL	87	225.33	31.17	128.25	67.83	113.33	90.58
ICPL	161	47.33	22.83	35.08	55.5	70.17	62.84
ICPL	8863	46.67	31.50	39.09	150.33	46.17	98.25
ICPL	85063	45.67	24.67	35.08	187.17	56.00	121.59
ICPL	87119	57.17	39.00	48.09	185.00	56.33	120.67
ICPL	7120	18.50	44.17	31.34	75.83	42.50	59.17
ICEAP	00068	79.50	56.50	68.00	69.00	23.67	46.34
ICPL	8094	131.00	43.33	87.17	68.17	53.67	60.92
ICPL	7035	45.67	13.33	29.50	105.50	53.67	79.59
ICPL	87051	84.00	63.50	73.75	154.17	42.50	98.34
ICPL	9145	48.50	43.33	45.92	45.33	40.83	93.08
ICPL	00040	32.50	6.50	24.50	91.50	34.67	63.09
ICEAP	00040	32.50	6.50	24.50	91.50	34.67	63.09
Igbongbo		25.17	14.33	29.75	91.17	53.50	72.34
Mean		1.20		1.13			1.20
F-LSD (0.05)							
CS		1.20			1.13		
GE		1.68			2.55		
CSXGE		2.36			3.67		

CS: Cropping System
GE: Genotype

RESULTS

Intercropping caused reduction in the number of nodules produced per plant of pigeonpea genotype intercropped with sorghum except for ICPL 7120 in 2002 and ICPL 85010, ICPL 84031, ICPL 87 and ICPL 161 in 2003 where the reverse trend was observed (Table 1).

ICPL 87 produced the largest number of nodules (225.3) per plant of pigeon pea under monocropping in 2002, but not so in 2003, when ICPL 85063 produced the highest number of nodules (187.1) per plant (Table 1). Under intercropping situation, ICPL 87051 had significantly higher number of nodules (63.5) per plant than all other genotypes of pigeon pea in 2002, while ICPL 84031 had the highest number of nodules (123.1) per plant in 2003. The cropping system means indicate that sole cropping consistently gave higher number of nodules per plant than the intercrop situation in both years. Similarly, intercropping decreased nodule biomass production in such genotypes as ICPL 87 and *Igbongbo* and increased that of ICPL 8863, ICPL 85063, and ICPL 7120 in the two years of experimentation (Table 2). The effect of intercropping on nodule biomass yield of the remaining genotypes tested seemed inconsistent as reflected by the cropping system means. In 2002, monocropping had significantly higher nodule biomass (x=2.02g) than intercropping (x = 0.85g), while in 2003, intercropping produced higher nodule biomass (x =2.82g) than monocropping (x = 2.05g) (Table 2).

Table 2: Nodule biomass (g) of pigeonpea genotypes as affected by intercropping with sorghum.

		Cropping System					
		2002			2003		
Pigeonpea	Genotypes	Sole crop	Intercrop	Mean	Sole crop	Intercrop	Mean
ICPL	**85010**	**1.27**	**1.40**	**1.34**	**2.40**	**1.92**	**2.16**
ICPL	84031	1.53	0.87	1.2 0	2.33	2.37	2.35
ICPL	87	1.87	1.10	1.4 9	4.40	1.12	2.76
ICPL	161	0.93	0.33	0.63	1.70	3.13	2.42
ICPL	**8863**	**0.90**	**1.07**	**0.98**	**1.33**	**4.37**	**3.52**
ICPL	85063	0.70	0.80	0.75	0.63	2.76	1.69
ICPL	87119	0.83	0.60	0.72	1.07	4.18	2.63
ICPL	7120	0.53	0.87	0.70	2.10	3.73	2.92
ICEAP	00068	1.10	0.87	0.98	1.50	2.73	2.12
ICPL	8094	1.06	1.28	1.17	1.88	1.28	1.58
ICPL	7035	0.70	0.50	0.60	2.77	2.37	2.57
ICPL	87051	1.57	1.10	1.34	2.13	4.80	3.47
ICPL	9145	1.30	1.03	1.17	1.73	3.23	2.48
ICEAP	00040	0.60	0.53	0.57	1.80	1.98	1.89
Igbongbo		0.47	0.38	0.43	3.03	2.33	2.68
Mean		**1.02**	**0.85**	**0.94**	**2.05**	**2.82**	**2.44**
FLSD(0.05)							
CS		0.25			0.38		
GE		0.21			0.48		
CS X GE		0.29			0.67		

CS: Cropping System
GE: Genotype

Table 3: Leaf litter (t/ha) of pigeonpea genotypes as affected by intercropping with sorghum.

		Cropping System					
		2002			2003		
Pigeonpea	Genotypes	Sole crop	Intercrop	Mean	Sole crop	Intercrop	Mean
ICPL	85010	1.28	0.75	1.02	1.35	0.52	0.94
ICPL	84031	1.11	0.66	0.89	0.85	0.27	0.56
ICPL	87	1.07	0.67	0.87	1.27	0.46	0.87
ICPL	161	1.24	0.82	1.03	2.54	1.17	1.86
ICPL	8863	1.07	0.69	0.88	2.55	0.65	1.60
ICPL	85063	1.20	0.59	0.89	2.35	1.18	1.77
ICPL	87119	1.49	0.79	1.14	1.74	1.12	1.43
ICPL	7120	1.63	0.75	1.19	1.56	0.51	1.04
ICEAP	00068	1.69	0.84	1.27	0.93	0.37	0.65
ICPL	8094	2.03	1.22	1.63	3.70	1.58	2.64
ICPL	7035	1.39	0.62	1.01	2.49	1.02	1.76
ICPL	87051	1.39	0.84	1.12	2.56	1.12	1.84
ICPL	9145	1.30	0.64	0.97	3.77	0.94	2.36
ICEAP	00040	1.13	0.58	0.86	2.88	0.93	1.91
Igbongbo		1.33	0.60	0.97	1.56	0.81	1.19
Mean		1.35	0.76	1.06	2.14	0.79	1.47
F-LSD (0.05)							
CS		0.51			0.08		
GE		0.08			0.08		
CS X GE		0.24			0.12		

CS: Cropping System
GE: Genotype

Table 3 shows the leaf litter produced by pigeon pea genotypes intercropped with sorghum. Intercropping reduced leaf litter produced by pigeon pea in all genotypes for both years of the study. The reductions were to about 50% level in most situations, but some were as low as 25% (e.g. ICPL 8863 in 2003) of the monocrop leaf litter produced. ICPL 8094 gave higher leaf litter in both years under monocropping (2.0 t/ha in 2002, and 3.7 t/ha in 2003) than all other genotypes of pigeon pea tested, except for ICPL 9145 in 2003, which produced 3.8 t/ha of leaf litter. Similarly, significant reductions of the shoot dry weight of intercropped pigeon pea as compared to monocropped pigeon pea occurred in all genotypes for both years except in *Igbongbo* in 2002 (Table 4). Only ICPL 9145 and ICPL 7120 produced shoot dry matter above 19.00 t/ha under monocroping in 2002, but all genotypes except ICPL 7120 yielded shoot dry weight above 20.0 t/ha under monocropping in 2003. In intercropping, genotypes such as ICPL 87, ICPL 8094, ICPL 7035 and ICEAP 0040 out-yielded the other genotypes in shoot dry weight production in 2002, but ICPL 87 singularly did so in 2003. ICPL 87051, however, produced the highest shoot dry weight (41.8 t/ha) under monocropping in 2003 (Table 4).

Table 4: Shoot dry weight (t/ha) of pigeonpea genotypes as affected by intercropping with sorghum.

		Cropping System					
		2002			2003		
Pigeonpea	Genotypes	Sole crop	Intercrop	Mean	Sole crop	Intercrop	Mean
ICPL	**85010**	**16.39**	**9.17**	**12.78**	**24.70**	**13.17**	**18.94**
ICPL	84031	12.09	11.17	11.53	35.60	12.34	28.97
ICPL	87	17.18	14.41	15.79	40.00	17.51	29.76
ICPL	161	18.48	10.63	14.56	26.10	10.48	18.19
ICPL	8863	14.20	11.10	12.65	21.98	9.98	13.98
ICPL	85063	18.94	12.02	15.48	31.58	13.89	22.74
ICPL	87119	12.74	11.06	11.90	20.81	12.69	16.75
ICPL	7120	19.04	13.52	16.78	16.55	11.24	13.89
ICEAP	00068	16.61	12.70	14.66	23.43	13.52	18.48
ICPL	8094	18.85	14.98	16.92	28.94	9.98	19.46
ICPL	7035	18.47	14.09	16.28	37.59	16.76	27.17
ICPL	87051	15.96	11.58	13.77	41.82	11.39	26.61
ICPL	9145	19.64	11.83	15.74	27.69	12.55	20.12
ICEAP	00040	14.86	14.07	14.47	24.06	7.49	15.78
Igbongbo		12.74	12.07	12.41	22.92	8.39	15.66
Mean		16.41	12.29	14.35	28.29	12.09	20.19
F-LSD (0.05)							
CS		***1.27***			***3.18***		
GE		***0.59***			***0.71***		
CS X GE		***0.87***			**0.99**		

CS: Cropping System
GE: Genotype

Table 5: Total N (g/100g) of soil at harvest under intercropping of pigeonpea genotypes and sorghum.

		Total soil N (g/100g)					
		2002			2003		
Crop	Genotypes	Sole crop	Intercrop	Mean	Sole crop	Intercrop	Mean
ICPL	85010	0.82	0.78	0.80	0.92	0.83	**0.86**
ICPL	84031	0.82	0.88	0.85	0.83	1.00	**0.92**
ICPL	87	0.81	0.86	0.84	0.83	0.94	0.89
ICPL	161	0.80	0.84	0.82	0.84	0.86	0.85
ICPL	8863	0.86	0.80	0.83	0.91	0.89	0.90
ICPL	5063	0.71	0.74	0.73	0.83	0.81	0.82
ICPL	87119	0.77	0.74	0.76	0.79	0.76	0.76
ICPL	7120	0.79	0.78	0.79	0.80	0.80	0.80
ICEAP	00068	0.89	0.88	0.89	1.03	1.03	1.03
ICPL	8094	0.84	0.76	0.80	0.90	0.85	0.88
ICPL	7035	0.85	0.73	0.79	0.84	0.81	0.83
ICPL	87051	0.81	0.76	0.79	0.86	0.84	0.85
ICPL	9145	0.77	0.88	0.83	0.79	0.99	0.88
ICEAP	00040	0.94	0.92	0.93	1.01	1.00	1.01
Igbongbo		0.96	0.93	0.95	1.03	1.01	1.02
Mean		0.83	0.82	0.83	0.88	0.89	0.89
Fallow		0.71	-	-	-	0.71	-
t-2tailed (0.05)		0.04^{NS}			0.03^{NS}		

Total nitrogen of soil at harvest under intercropping of pigeon pea genotypes with sorghum (Table 5) showed no significant difference from the soils under monocropping in both years as indicated by the means.

However, the total nitrogen yield of soils under both monocropping and intercropping in 2003 were superior to those of 2002. Also, the preplant soil test revealed higher levels of total nitrogen (1.04%) than the means of soil under both monocrop (0.88%) and intercrop (0.89%) in 2003, which were in turn higher than the total N result obtained from the preplant soil test (0.71%) in 2002. Soils under sole cropped pigeon pea gave total N ranging from 0.73-0.93% in 2002 and 0.79-1.03% in 2003, while that of intercropping varied from 0.73-0.93% in 2002 and from 0.76-1.03% in 2003. Total nitrogen concentration in the seed, leaf, stem, root, fallen parts (flowers, damaged fruits, leaf litter) and nodules of pigeon pea genotypes intercropped with sorghum in 2002 and 2003 are presented in Tables 6 and 7. Nodules had the highest concentration of total nitrogen among the plant parts of the pigeon pea genotypes intercropped with sorghum, followed by pod with seed, leaf, root, stem and fallen parts in that order.

Table 6: Total nitrogen concentration (%) in pod with seed, leaf, stem, root, fallen parts, and nodules of pigeon pea genotypes intercropped with sorghum in 2002.

		Total N Concentration (%)																	
		Pod with seed			*Leaf*			*Stem*			*Root*			*Fallen Part*			*Nodule*		
Crop/genotype		*Int.*	*Sole*	*Mean*	*Int.*	*Sole*	*Mean*	*Int.*	*Sole*	*Mean*	*Int.*	*Sole*	*Mean*	*Int.*	*Sole*	*Mean*	*Int.*	*Sole*	*Me*
Pigeonpea																			
ICPL	85010	46	2.92	2.69	2.44	3.21	2.83	1.31	1.18	1.25	2.29	1.47	88	0.97	1.29	1.13	4.65	4.61	4.6
ICPL	84031	3.04	3.38	3.21	2.41	3.20	2.81	1.59	1.38	1.49	2.82	1.55	2.19	0.95	1.26	1.11	4.60	4.56	4.5
ICPL	87	3.27	3.43	3.35	2.68	2.61	2.65	1.91	1.44	1.68	2.29	1.48	1.89	1.05	1.02	1.04	4.50	4.58	4.5
ICPL	161	3.37	3.57	3.47	2.64	2.83	2.74	1.56	1.49	1.53	3.01	1.58	2.30	1.03	1.13	1.08	4.64	4.62	4.6
ICPL	8863	1.78	2.04	1.91	2.55	2.67	2.61	1.42	1.85	1.64	1.66	3.20	2.43	1.01	1.05	1.03	3.99	3.98	3.9
ICPL	85063	2.64	3.40	3.02	2.33	2.52	2.43	1.34	1.77	1.56	1.46	2.13	1.80	1.88	0.99	1.44	3.80	3.87	3.8
ICPL	87119	2.62	3.43	3.03	2.49	2.57	2.53	1.22	1.38	1.30	1.70	2.85	2.26	0.99	1.02	1.01	3.92	3.98	3.9
ICPL	7120	3.43	3.61	3.52	2.98	2.57	2.76	1.49	1.72	1.61	1.84	3.91	2.88	1.18	1.01	1.10	4.02	4.16	4.0
ICEAP	00068	1.79	2.02	1.91	2.96	2.40	2.68	1.45	1.70	1.58	0.93	1.50	1.22	1.17	0.90	1.04	3.87	3.91	3.8
ICPL	8094	1.77	2.04	1.91	2.76	2.79	2.76	1.62	1.70	1.66	3.54	2.02	2.78	1.09	1.11	1.10	4.88	4.92	4.9
ICPL	7035	2.09	2.41	2.25	2.52	2.49	2.51	1.42	1.63	1.53	4.27	2.64	3.46	0.99	1.98	0.99	4.96	4.98	4.9
ICPL	87051	2.28	2.55	2.42	2.44	2.49	2.47	1.36	1.67	1.52	2.31	1.81	2.06	0.94	0.96	0.95	4.80	4.88	4.8
ICPL	1945	2.07	2.38	2.23	2.50	2.45	2.48	1.58	1.62	1.60	2.08	1.74	1.91	0.99	0.96	0.98	4.78	4.72	4.7
ICEAP	00040	2.24	2.79	2.52	2.58	2.50	2.54	1.37	1.63	1.50	2.11	1.51	1.81	1.02	0.97	1.00	4.75	4.76	4.7
Igbongbo		3.29	3.54	3.42	2.62	2.86	2.74	1.71	1.51	1.61	0.99	1.23	1.11	1.03	1.13	1.08	2.96	2.92	2.9
Mean		2.54	2.90	2.72	2.59	2.68	2.14	1.49	1.58	1.54	2.22	2.04	2.13	1.02	1.05	1.04	4.34	4.36	4.3
t-2tailed			-7.37^{*}			$--0.38^{NS}$			-1.41^{NS}			0.64^{NS}			-0.35^{NS}				

nt: **Intercroppingle:** **sole** **Sole cropping**
*: Significant at 5%
NS: non Significant

Table 7: Total nitrogen concentration (%) in pod with seed, leaf, stem, root, fallen parts, and nodules of pigeon pea genotypes intercropped with sorghum in 2003.

Total N Concentration (%)																			
		Pod with seed			*Leaf*			*Stem*			*Root*			*Fallen Part s*			*Nodule*		
Crop/genotype		*Int.*	*Sole*	*Mean*	*Int.*	*Sole*	*Mean*	*Int.*	*Sole*	*Mean*	*Int.*	*Sole*	*Mean*	*Int.*	*Sole*	*Mean*	*Int.*	*Sole*	*Mean*
Pigeon pea																			
ICPL	85010	2.89	3.45	3.17	2.89	3.82	3.36	1.54	1.39	1.47	2.69	1.72	2.21	1.16	1.52	1.34	5.81	5.76	5.79
ICPL	84031	3.61	4.00	3.81	2.83	3.78	3.31	1.86	1.61	1.74	3.32	1.80	2.56	1.13	1.50	1.32	5.75	5.71	5.73
ICPL	87	3.85	4.03	3.94	3.13	3.07	3.10	2.22	1.68	1.95	2.69	1.72	2.21	1.25	1.23	1.24	5.68	5.72	5.70
ICPL	161	3.97	4.20	4.09	3.11	3.33	3.22	1.81	1.73	1.77	3.54	1.84	2.69	1.25	1.33	1.29	5.80	5.78	5.79
ICPL	8863	2.10	2.40	2.25	3.00	3.10	3.10	1.65	2.15	1.90	1.95	3.76	2.86	1.20	1.24	1.22	4.99	4.98	4.99
ICPL	85063	3.10	4.00	3.55	2.74	2.96	2.85	1.56	2.52	2.04	1.70	2.50	2.10	1.05	1.17	1.10	4.75	4.84	4.80
ICPL	87119	3.10	4.03	3.57	2.94	2.99	2.97	1.42	1.98	1.70	2.00	3.35	2.68	1.16	1.19	1.18	4.90	4.98	4.94
ICPL	7120	4.04	4.25	4.15	3.51	3.02	3.27	1.73	2.00	1.87	2.16	4.60	3.38	1.41	1.21	1.31	5.02	5.20	5.11
ICEAP	00068	2.10	2.61	2.36	3.51	2.82	3.17	1.69	1.98	1.86	1.09	1.77	1.43	1.19	1.13	1.16	4.84	4.89	4.87
ICPL	8094	2.10	2.41	2.26	3.24	3.25	3.25	1.88	1.98	1.93	4.17	2.35	3.26	1.29	1.31	1.30	6.10	6.15	6.13
ICPL	7035	2.47	2.84	2.66	2.96	2.94	2.95	1.65	1.89	1.77	5.02	3.07	4.05	1.19	1.16	1.18	6.20	6.21	6.21
ICPL	87051	2.67	3.00	2.84	2.84	2.89	2.87	1.58	1.94	1.76	2.69	2.10	2.40	1.12	1.15	1.14	6.00	6.10	6.10
ICPL	1945	2.43	2.80	2.62	2.94	2.88	2.91	1.84	1.88	1.86	2.43	2.02	2.23	1.18	1.15	1.17	5.58	5.90	5.74
ICEAP	00040	2.64	3.28	2.96	3.04	2.91	2.98	1.60	1.89	1.75	2.45	1.75	2.10	1.21	1.16	1.19	6.00	6.10	6.10
Farmer's	Variety	3.88	4.16	4.02	3.08	3.36	3.22	2.00	1.75	1.88	1.15	1.43	1.29	1.23	1.39	1.31	3.70	3.69	3.70
Mean		2.99	3.43	3.21	3.05	3.14	3.10	1.74	1.89	1.82	2.60	2.39	2.50	1.20	1.25	1.23	5.43	5.47	5.45
t-2tailed		-7.71*			-0.88NS			-1.70NS			0.65NS			-1.49NS		-2.51*			

Int Intercropping
Sole: Sole cropping

The total nitrogen concentration was higher in sole cropped pigeon pea plant parts than in intercropped pigeon pea, particularly, in pod with seed and nodules. The concentration of total N in nodules and fallen parts were nearly the same, irrespective of the cropping system adopted. The results of total N concentration in pigeon pea plant parts in intercrop or monocrop for both years of experimentation showed a similar trend. The interaction between cropping systems and genotypes on the nitrogen yield of shoot of pigeon pea genotypes intercropped with sorghum was not significant in both 2002 and 2003 (Table 8). The total nitrogen yield of shoot of pigeon pea varied significantly with pigeon pea genotypes and ICPL 87 had the highest total nitrogen yield of shoot in both years of experimentation under intercropping. The influence of cropping systems on nitrogen yield of pigeon pea genotypes intercropped with sorghum was inconsistent in both years of the study. The total N yield of shoot of sole sorghum was superior to that of intercropped sorghum combined with all pigeon pea genotypes in 2002 and 2003, except ICPL 7120 in both years, and ICPL 87, ICPL 87051 and *Igbongbo* in 2003 (Table 9). Mean total nitrogen concentration of shoot of intercropped pigeon pea genotypes at harvest in both years (2.38%) was higher than that of intercropped sorghum (1.83%) in both years combined (Tables 8 and 9).

Table 8: Total N yield (g/100g) of the shoot of pigeon pea genotypes as influenced by intercropping with sorghum.

			Total soil N (g/100g)					
			2002			2003		
Crop	Genotypes	Group	Sole Crop	Intercrop	Mean	Sole crop	Intercrop	Mean
ICPL	85010	S	2.03	2.05	2.04	2.35	2.41	2.38
ICPL	84031	S	2.22	2.25	2.24	2.50	2.54	2.52
ICPL	87	S	2.60	2.67	2.64	2.81	2.89	2.85
ICPL	161	S	2.30	2.37	2.34	2.70	2.78	2.74
Mean		-	2.29	2.34	2.32	2.59	2.66	2.61
ICPL	8863	M	1.90	1.94	1.92	2.40	2.41	2.41
ICPL	85063	M	2.00	2.00	2.00	2.50	2.50	2.50
ICPL	87119	M	2.10	2.13	2.12	2.41	2.48	2.45
ICPL	7120	M	2.55	2.61	2.58	2.90	2.92	2.91
ICEAP	00068	M	1.99	2.10	2.05	2.50	2.55	2.53
Mean		-	2.11	2.16	2.14	2.54	2.57	2.56
ICPL	8094	L	1.96	2.00	1.98	2.42	2.49	2.46
ICPL	7035	L	2.10	2.15	2.13	2.44	2.51	2.48
ICPL	87051	L	1.95	1.99	1.97	2.35	2.43	2.39
ICPL	9145	L	1.99	2.10	2.05	2.41	2.44	2.43
ICEAP	00040	L	2.00	2.01	2.01	2.50	2.53	2.52
Mean		-	2.00	2.05	2.03	2.42	2.48	2.45
Igbongbo			2.50	2.55	2.53	2.75	2.81	2.78
Mean			2.15	2.19	2.17	2.52	2.57	2.55
FLSD (0.05)								
CS				0.02			0.02	
GE				0.06			0.06	
CS X GE				NS			NS	

S = Short Duration
M = Medium
L = Long Duration

Table 9: Total N yield (g/100g) of shoot sorghum intercropped with pigeon pea genotypes

			Total N yield (g/100g)		
Cropping System			Year 2002	Year 2003	Mean
Sole Sorghum at 1.0m Inter-row spacing			1.84	2.01	1.93
Intercropped Sorghum					
In	ICPL	85010	1.74	1.92	1.83
”	ICPL	84031	1.68	1.71	1.70
”	ICPL	87	1.82	1.86	1.84
”	ICPL	161	1.78	1.94	1.86
”	ICPL	8863	1.79	1.88	1.84
”	ICPL	85063	1.83	1.91	1.87
”	ICPL	87119	1.76	1.88	1.82
”	ICPL	7120	1.88	2.01	1.95
”	ICEAP	00068	1.69	1.75	1.72
”	ICPL	8094	1.81	1.90	1.86
”	ICPL	7035	1.88	1.95	1.92
”	ICPL	87051	1.82	1.90	1.86
”	ICPL	9145	1.77	1.87	1.82
”	ICEAP	00040	1.65	1.76	1.71
”	Igbongbo	1.82	1.85	1.84	1.83
Mean for Intercropping			1.17	1.87	1.83
FLSD (0.05)			0.06	0.04	

Table 10: Total nitrogen fixed by pigeon pea genotypes as affected by intercropping with sorghum

Pigeon pea Genotype		Maturity Group	Total nitrogen fixed: Year 2002 P(%)	Year 2002 Amount (Kg/ha)	Year 2003 P(%)	Year 2003 Amount (Kg/ha)	MEAN P(%)	MEAN Amount (kg/ha)
ICPL	85010	S	0.31	28. 45	0.04	60.60	0.39	44.53
ICPL	84031	S	0.67	75.15	0.97	119.72	0.82	97.44
ICPL	87	S	0.93	134.83	1.11	194.80	1.02	164.82
ICPL	161	S	0.65	69.55	0.84	88.03	0.75	78.79
Mean			0.64	77.00	0.85	115.79	0.75	96.40
ICPL	8863	M	0.17	18.76	0.54	56.28	0.37	37.52
ICPL	85063	M	0.13	15.59	0.56	74.99	0.34	45.29
ICPL	87119	M	0.33	36.49	0.50	63.40	0.42	49.95
ICPL	7120	M	0.73	98.59	0.85	95.53	0.79	97.06
ICEAP	0068	M	0.51	64.97	0.97	131.16	0.74	98.07
Mean			0.37	46.88	0.68	84.27	0.53	68.58
ICPL	8094	L_1	0.17	25.26	0.58	58.11	0.38	41.69
ICPL	7035	L	0.25	34.70	0.51	85.56	0.38	60.13
ICPL	87051	L	0.15	17.54	0.51	58.09	0.33	37.82
ICPL	9145	L	0.43	50.84	0.70	87.93	0.57	67.39
ICEAP	00040	L	0.50	70.31	0.91	68.30	0.71	69.31
Mean			0.30	39.73	0.64	71.60	0.47	55.69
Igbongbo			0.88	106.32	1.11	93.15	1.00	99.74
Mean			0.45	56.49	0.74	89.04	0.60	72.77
FLSD(0.05)			0.06	17.08	0.06	10.42	-	-

Total nitrogen fixed by pigeon pea under intercropping with sorghum varied with the genotypes and ICPL 87 had the highest value of nitrogen fixation in both years of experimentation(Table 10). Though ICPL 87 had similar values of the proportion of nitrogen fixed (P) with *Igbongbo*, the total nitrogen fixed by ICPL 87 in kg/ha was significantly superior to that of *Igbongbo*. Nitrogen fixation by pigeon pea genotypes intercropped with sorghum ranged from 15.59 to 134.83 kg/ha in 2002 and from 56.28 to 194.80 kg/ha in 2003 .The means revealed that the short duration genotypes fixed greater amount of total nitrogen per ha per year (96.40 kg/ha) than the medium duration (68.58 kg/ha) and the long duration (55.69 kg/ha) genotypes of pigeon pea. Nitrogen fixed in 2003 was higher than that fixed in 2002

DISCUSSION

Nodulation is important in nitrogen fixation by legumes. The reduction recorded in intercropping when compared to Mônocropping in the number of nodules per plant of pigeon pea, except in ICPL 7120 (medium duration) in 2002, ICPL 85010, ICPL 84031, ICPL87 and ICPL161 (short duration) was probably due to shading effect, which reduced the amount of light available to the intercropped plants. This result was consistent with the findings of earlier workers (Nambiar *et al*; 1983; Wahua and Miller, 1978) who observed reduced nodulation and nitrogen fixation by groundnut cultivars mixed with sorghum and attributed the response to the effects of shading. The exceptional response of ICPL 7120 in 2002 and the early-maturing genotypes (ICPL 85010, ICPL 84031, ICPL 87, ICPL 161) under intercropping in 2003, suggested that shading from the sorghum might not have been intense enough to influence nodulation in these genotypes, considering the time (56 days after planting) at which nodulation score was done. The decreased nodule biomass of ICPL 87 and *Igbongbo* under intercropping with sorghum was in agreement with the findings of Nambiar *et al.* (1983) who reported decreased nodule dry weight of groundnut intercropped with sorghum, millet and maize. Kaleem (2000) similarly reported decreased nodule biomass in soybean intercropped with sorghum. These workers attributed this response to adverse shading effects due to the tall cereal canopy. Reduced light in intercropping situations could affect nodule biomass by restricting photosynthesis of the pigeon pea shoots and consequently the energy supply to the nodules. But other workers (Searle *et al.*, 1981) have also found that this negative response observed with ICPL 87 and *Igbongbo* under intercropping is not invariably the case as found with ICPL 8863, ICPL 85063 and ICPL 7120, which had increased nodule biomass. The erratic response of the other intercropped pigeon pea genotypes with sorghum in nodule biomass yield might have resulted from the different distribution of rainfall received in the two experimental years. Some earlier workers (Kumar Rao and Dart, 1979; Thompson *et al.*, 1981) reported that nodule formation and development are affected by soil type, the season and the duration of the cultivars of pigeon pea. The reduction in leaf litter of pigeon pea intercropped with sorghum as compared to monocrop situation might be due mainly to the fewer number of plants in intercropped plots as compared to the plants in sole crop environment. The means of leaf litter produced by pigeon pea under intercropping in 2002 (0.76 t/ha) and in 2003 (0.79 t/ha) are small compared to the 3.0 t/ha of leaf fall from intercropping of pigeon pea with maize in Malawi (Sakala, 1994). Sakala (1994) further stated that if seeds of intercropped plants are harvested for food, the leaf fall is sufficient to make a significant contribution to N accumulation. Kumar Rao *et al.* (1983) also reported less leaf fall under intercropping than in pure stands.

Significant reductions in shoot dry weight of intercropped pigeon pea as compared to sole pigeon pea might derive from reductions of dry stem weight, leaf weight, dry pod weight and dry grain yield (data not provided). Earlier studies in pigeon pea +sorghum intercropping (Kumar Rao *et al.*,1983; Natarajan and Willey, 1980a; Tobita *et al.*,1996; Katayama *et al.*,1995) reported severe reductions in shoot growth and consequently dry matter accumulation in the shoot of intercropped pigeon pea as compared to Monocropping. These reports further explained that the canopy of the cereal develops more rapidly and is relatively unaffected by the intercrop, whereas the pigeon pea canopy is shaded and its growth is substantially reduced and consequently accumulation of dry matter is drastically reduced in the shoot. Soils under both mono- and inter-crop pigeon pea had slightly higher N than soils under mono- and inter-crop sorghum in either of the years, although this was not statistically significant. Soils under Môn cropped pigeon pea gave total N of soils ranging from 0.73-0.96% in 2002 and 0.79-1.03% in 2003 while that of intercropping varied from

0.73-0.93 in 2002 and 0.76-1.03 in 2003. Wani *et al.* (1996) reported higher mineral N content in soils under legume as compared to non-legume at ICRISAT Asia Centre (IAC), India.

Intercropped pigeon pea plant parts accumulated less N compared to the Môn cropped pigeon pea plant parts. This is in agreement with the findings of Tobita *et al.*(1996) that less N was accumulated in the shoot of intercropped pigeon pea than of sole pigeon pea. This might be due to shading and competition for N between the intercrop components. The higher concentration of N in pods with seeds as compared to leaves and stem were similar to the observations of Devries (1986) and Lawson and Troedson (1990) that between 28 and 56% of the N accumulated by the pigeon pea shoots was recovered in the seeds. Several reports (Kumar Rao *et* al., 1983; Giller, 2001) have shown that N concentration is highest in nodules of all plant parts in pigeon pea, consistent with the observations in the current study. This suggested that inter-species competition and shading might have exerted more effect on N-accumulation under intercropping environment. This is consistent with the findings of Kumar Rao *et al.* (1983) and Tobita *et al.* (1996). The interaction between cropping systems and genotypes on the nitrogen yield of shoot of pigeon pea genotypes intercropped with sorghum was not significant in both 2002 and 2003. The total nitrogen yield of shoot of pigeon pea varied significantly with pigeon pea genotype. The high dependence of shoot N on pigeon pea genotype rather than on the pigeon pea/sorghum intercropping system agreed with the findings of Kaleem (2000) which revealed variability in N yield among soybean cultivars intercropped with sorghum. The total nitrogen yield of shoot in intercropped pigeon pea genotype at harvest in both years (2.57%) was higher than that of intercropped sorghum (1.83%) in both years combined. The values of total N yield of shoots of intercrop pigeon pea and sorghum obtained in this work were higher than the 1.49% and 0.52% for pigeon pea and sorghum, respectively obtained by Ito *et al.* (1997) indicating higher N values for shoot of pigeon pea than shoot of sorghum.

The total nitrogen fixed by pigeon pea under intercropping with sorghum varied with the genotypes while ICPL 87 had the highest value of the nitrogen fixed in both years of experimentation. The significant variability in biological nitrogen fixation among pigeon pea genotypes intercropped with sorghum supported earlier findings of Kumar Rao *et al.* (1983) and Kumar Rao *et al.* (1996) that variability existed among legumes and genotypes of legumes in the amount of N fixed and the proportion of plant – N derived from biological nitrogen fixation. ICPL 87 fixed the highest amount of N (164.82kg/ha), followed by *Igbongbo* (99.74kg/ha). The good performance of *Igbongbo* in nitrogen fixation in the pigeonpea/sorghum intercrop might be ascribed to its long association with the indigenous symbiotic *bradyrhizobia*. The values of the atmospheric nitrogen fixed by pigeon pea under intercropping with sorghum were comparable to values reported by Peoples and Craswell (1992). Results showed clearly that pigeon pea under intercropping with sorghum can lead to a reduction of nitrogenous fertilizer use of up to 37.52 -164.82 kg N/ha depending on the pigeon pea genotype.

REFRENCES

Adu–Gyamfi, J.J; O.Ito; T.Yenoyama and K.Katayama (1997). Nitrogen management and biological nitrogen fixation in sorghum/pigeonpea intercropping on Alfisols of the Semi-Arid Tropics. *Soil Sci. Nutr*; 43:061–1066.

Chaykin, S. (1969). Assay of nicotinamide deamoinase. Determination of ammonium by the indophenol reaction. *Anal. Biochem* 32 : 375 – 382.

De Vries, J.D. (1986). Water relations and nitrogen fixation of three grain legumes during water stress. MSC thesis, University of Florida, USA, 107pp.

GENSTAT (1995). GENSTAT – a general statistical program Release 3.2 (*Copyright* 1995) Lawes Agricultural Trust Rothamsted Experimental Station.

Ito, O; R. Matsunaga, S. Tobita, J.J. Adu-Gyamfi; K.Katayama, T.P. Rao and Gayatari Deri (1997). Nitrogen fertilizer management in pigeonpea/ sorghum intercropping on an Alfisol in the semi-arid tropics. *Plant* nutrition-for sustainable food production and environment. Kluwer Academic Publishers, Japan pp 689-690.

Kaleem, F. (2000). Biological nitrogen fixation in a soybean/sorghum intercropping system. *In*: Karanja, N. and Kahindi, J.H.P. (eds). Challenges and imperatives for biological nitrogen fixation research and application in Africa for the 21st century. Proceedings of the 9th Conference of the African Association for Biological Nitrogen Fixation, 25-29th September, 2000, Nairobi, Kenya. pp 50-62.

Katayama, K.; O.Ito; R.Matsunaga; J.J.Adu-Gyamfi; T.P Rego and M.M.Anders (1995). Nitrogen balance and root behaviour in four pigeon pea-based intercropping systems. *Fert.Res.* 42:315-319.

Kowal, J.M. and Knabe, D.T. (1972). An agroclimatological Atlas of Northern States of Nigeria. Ahmadu Bello University Press, Zaria. 23pp.

Kumar Rao, J.V.D.K. and P.J.Dart (1987). Nodulation, nitrogen fixation and nitrogen uptake in pigeonpea (*Cajanus cajan* (L.) Millsp.) of different maturity groups. *Plant and Soil* 99 : 255-266.

Kumar Rao, J.V.D.K. and P.J.Dart and P.V.S.S. Sastry (1983). Residual effect of pigeonpea (*Cajanus cajan* (L.) Millsp). on yield and nitrogen response of maize. *Exptal. Agric.* 19:131 – 141.

Kumar Rao, J.V.D.K; J.A. Thompson; P.V.S.S. Sastry; K.E.Giller and J.M. Day (1987). Measurement of N_2 fixation in field growing pigeonpeas (*Cajanus cajan (L.) Millsp.*) using ^{15}N labelled fertilizer. *Plant and Soil* 101:107-113.

Kumar Rao, J.V.D.K; S.P. Wani and K.K. Lee (1996). Biological nitrogen fixation through grain legumes in different cropping systems of the semi-arid tropics. *In*: Ito, O; K.Katayama; C.Johansen; J.V.D.K. Kumar Rao; J.J. Adu-Gyamfi and T.J. Rego (eds.) Roots and nitrogen in cropping systems of the semi-arid tr Egbe, O.M. rnational Agricultural Series No.3; Ohwashi, Tsukuba, Japan, pp 323-334.

Nambiar, P.C.T; M.R.Reddy, M.S.Floyd, C .Dartand R.W.Willey (1983). Effect of intercropping on nodulation and N_2 fixation by groundnut. *Exptal Agric*. 19:79-86.

Ofori, F. and W.R. Stern (1987). Cereal-legume intercropping systems. *Adv. Agron*. 41: 41-90.

Obi, I.U. (1986). Statistical method of detecting differences between treatment means. SNAAP Press (Nig.) Ltd; Enugu, Nigeria. p 1-14.

Papastylianon, I. (1999). Estimation of nitrogen fixed in long vs. short-term cropping systems. *Agron.J.* (1) 91:329-334.

Peoples, M.B. and E.T.Craswell (1992). Biological nitrogen fixation: investments, expectations, and actual contributions to agriculture. *Plant and Soil* 141:13-40.

Sakala, W.D.M. (1994). Crop management interventions in traditional maize/pigeonpea intercropping systems in Malawi. M.Sc. thesis. Lilongwe, Malawi: Bunda College of Agriculture, University of Malawi.

Searle, P.G.E; C.Yuthapang; D.C. Shedden and R.A. Mance (1981). Effect of maize + legume intercropping systems and fertilizer nitrogen on crop yields and residual nitrogen. *Field crops Res*. 4:133-145.

Tobita, S; O. Ito; Matsunaga; T.P. Rego; C.Johansen and T.Yoneyama (1994). Field evaluation and nitrogen fixation and use of nitrogen fertilizers by sorghum/pigeonpea intercropping on an Alfisol in the Indian semi-arid tropics. *Bio Fert. Soil* 17:241-248.

Wahua, T.A.T. and D.A.Miller (1978). Effects of shading on the nitrogen fixation, yield, and plant composition of field-grown soyabeans. *Agron .J.* 70:387-392.

Wani, S.P., T.J.Rego, O.Ito and K.K.Lee (1996) Improvement of soil and fertilizer nitrogen use efficiency in sorghum/pigeonpea intercropping in :Ito, O; Katayama, K; Johansen, C; Kumar Rao, J.V.D.K; Adu-Gyamfi, J.J and Rego, T.J (eds) Roots and Nitrogen in cropping systems of the semi-arid tropics. JIRCAS. International Agricultural Series No.3. Ohawashi, Tsukuba, Ibaraki 305, Japan. pp 481-492.