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Comparative Effects of Cowpea and Soybean Genotypes on N_2 - Fixation and N-Balance in Sokoto Dry Sub-Humid Agro-Ecological Zone of Nigeria.

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ABSTRACT:A field trial was conducted to asses N_2 - fixation and N balance in five cultivars each of soybean (TGX 1945 – 1F, TGX 1951 – 4F, TGX 36 – 54KT, TGX 1951 – 3F and TGX 1935 – 3F) and cowpea (IT88D-867-11, IT89KD-288, IT90K-l372-1-2, IT90K – 82-2 and Bahaushe (local). The legume genotypes and reference millet crop (ZM – 01- 58) were planted in a randomized complete block design with three replications. N difference method and the difference between N_2 - fixed and N exported in grain at harvest were used to estimate N_2 - fixed and N balance respectively. The biomass yield (2.9 to 5.23 t ha^{-1}) in cowpea cultivars were significantly ($P<0.05$) higher than in soybean (0.95 to 1.5 t ha^{-1}). Above ground cowpea biomass (vine plus litter) accumulated up to 81.03 kg N ha^{-1} which differed significantly from the 33.13 kg N ha^{-1} observed in soybean. N_2 - fixed that ranged from 42.27 to 59.07 kg N ha^{-1} in soybean cultivars was generally higher than those of cowpea. All the soybean cultivars recorded significantly ($P<0.05$) higher grain N than the cowpea. This explains the high percentage nitrogen harvest index (NHI) (64.33 to 70.22 %) and negative N balances (-9.47 to -1.2 kg N ha^{-1}) obtained in all the soybean genotypes. On account of the large above ground biomass and N content, positive N balances and low percentage N H I, cowpea appeared to perform better in contributing to soil N the following year.
Key words: Legume genotype, N_2 fixation, N balance and Nitrogen Harvest Index (NHI)

INTRODUCTION

Grain legumes have long been known to be important components of the traditional cropping systems in the tropics (Singh *et al.* 2003 and Yusuf *et al.*, 2006). Cowpea appears to be more prominent in the cereal based cropping system and is mostly grown as intercrop with cereals (millet and sorghum) and sometimes as a sole crop in the savanna (Yusuf *et al.*, 2006).

On the other hand soybean is relatively a new crop to most African countries, but, recently its cultivation and utilization in countries such as Nigeria, is gaining popularity over the past 10 – 15 years. This was consequent upon the increasing need for cheaper source of protein from food and animal fodder (Sanginga, 2003 and Yusuf *et al.,* 2006).

Unlike the several cowpea genotypes that are found on farmers' fields across the entire savanna agro-ecological zone of Nigeria, soybeans were found to be cultivated mainly in the Guinea Savanna (Carsky *et al.,* 1997 and Yusuf *et al.,* 2006). International Institute for Tropical Agriculture (IITA) and other agricultural institutes in Nigeria have embarked on breeding programmes which led to the introduction of high yielding, early maturing cowpea and soybean genotypes to replace the farmers' varieties (Osunde *et al.,* 2003; Bala *et al.,* 2003 and Yusuf *et al.,* 2006 and Singh *et al.*,1997).

Recent researches have revealed differences in the amount of N_2 – fixed by grain legumes (Osunde *et al.,* 2003 ; Bala *et al.,* 2003 and Yusuf *et al.,* 2006), thus, the need to select cultivars with superior ability for N_2 – fixation that will best suit a particular environment (Nutman, 1984) such as the dry sub- humid agro-ecological zone of Nigeria.

Legumes are also being considered for soil fertility improvements in cereal based cropping systems in the Northern and Southern Guinea savanna (Carsky *et al.,* 1997 and Yusuf *et al.,* 2006). They have the capacity to fix atmospheric nitrogen that enables them to grow well on N impoverished soils without adding fertilizer N and depleting the soil N resources. Reports have shown that the cultivation of legume results in an enhancement of soil N (Kaleem, 1993 and Carsky *et al.,* 1997). However, this has often been dependent on the proportion of the legume N_2 – fixed to that of N harvest index. Giller (2001) found out that for a beneficial residual effect to occur, the amount of fixed nitrogen returned by the legume to the soil must be greater than the amount of soil N in the harvested grain.

Since there is little or no information on the quantification of N – balance and N_2 - fixed by grain legumes in Sokoto dry sub humid agro-ecological zone of Nigeria, this research was therefore carried out to estimate the amount of N_2 – fixed and N- balance in five cultivars each of cowpea and soybean.

MATERIALS AND METHOD

Site Description: Sokoto, the capital of Sokoto state (11^0 30'-13^0 55'N; $4^0$07' - $6^0$56'E) is situated in the dry sub-humid agro-ecological zone. The vegetation in this zone is characterized with few scattered trees and numerous shrubs sandwiched by grasses and herbs. The research was carried out at Dabagi Farm of the Usmanu Danfodiyo University, Sokoto in 2008 cropping season. Dabagi Farm lies on 12^0 46'N and 05^0 26'E and is about 40 km south - east of Sokoto metropolis. The mean annual rainfall of Sokoto State is 565 mm (it occurs between May-October) and the average temperature is 27^0C with peak at 40^0C (in April) and 15^0C (December – January) (Singh, 2004 and Hamma, 2006)).

Soil sampling and analysis: Twenty core samples (0 – 15 cm) were taken at random within the experimental site before ridging and were bulked to form a composite sample. A sub – sample of the composite soil obtained through conning and quartering was sieved through a 2 mm sieve and subjected to routine soil analysis (IITA, 1989).

Treatments and experimental design: Five cultivars each of soybean (TGX 1935-3F, TGX 1945-1F, TGX 1951-3F, TGX 1951-4F and TGX 38-54KT) and Cowpea (IT88D-867-11 , IT89KD-288, IT90K-82-2, IT90K-372-1-2 and Bahaushe {local}) were used for the research. The seeds were obtained from IITA, Kano sub-station, except TGX 38-54KT and Bahaushe that were purchased from FASCO seeds and a local farmer in Sokoto respectively. The legumes were grown to maturity with non N fixing millet (SOSAT ZM-01-58) obtained from Ministry of Agriculture, Sokoto . The millet was used as a reference crop to estimate nitrogen fixation by the grain legume using N difference method (Hardarson and Danso, 1993). The experiment was laid out in a randomized complete block design replicated three times. Each experimental plot measured 16 m by 7.5 m, large enough to contain 10 ridges, 0.75 m apart. The intra row spacing for soybean and millet were 0.25 m and 0.50 m respectively. The net plot size was 2.25 by 8.0 m (40.50 m^2).

A starter N dose of 20 kg ha^{-1} N P K 15:15:15 was applied by single banding about 5 cm deep made along the ridges 5 – 10 cm away from the plant stand to both legumes (cowpea and soybean) and millet at two weeks after planting (WAP).

Four (4) seeds each of cowpea and soybean were sown per hole and thinned to 2 and 3 plants per stand at 2 WAP respectively based on recommendation of suppliers. Bahaushe (local) cowpea was thinned to three plants per stand to emulate farmers' practice. Five to ten (5 – 10) millet seeds were sown per hole and were later thinned to 2 at 2 WAP. Weeding was carried out in all the plots at 2 and 4 WAP.

Plant sampling and analysis: Plant sampling was confined to the inner four ridges (the net plot ridges). At 50% podding, three cowpea and soybean plants root were carefully dug out from each plot for nodule number determination, while shoot biomass within 1 m^2 were sampled at harvest for biomass yield. The legume cultivars were both sampled at harvest for litter (fallen leaves) and grain yields from within 1.5 by 1.5 m (2.25 m^2) quadrat and 9.0 m^2 net plot size respectively.

One millet reference crop was sampled for grain and stover N contents (Singh *et al.,* 2003). All the samples were air dried. Sub samples of the air dried cowpea and soybean grain, haulm, litter and millet grain and stover were milled and analyzed for N contents according to IITA (1989). The amount of N_2 – fixed was determined using N difference method (Danso, 1995), the N balance was determined by N difference between N fixed and N in grain (Peoples and Crasswall, 1992) and nitrogen harvest index (NHI) through percentage ratio of grain N to that of plant total N (Yusuf *et al.,* 2006).

Statistical analysis: Data were subjected to analysis of variance (ANOVA) using General Linear Model procedure of SAS (Statistical Analysis System, 1999). Means separation was done using Duncan Multiple Range test at 5% probability level.

RESULTS AND DISCUSSION

The result of the chemical and physical properties of the soil at the site is presented in table 1.

The soil at the study area was moderately acidic and belongs to the sandy loam textural class. Organic C, total nitrogen, available P. CEC and percent base saturation were generally low (Table 1). This indicates that the soil is of low fertility status.

Biomass and litter yield: Table 2 revealed that the biomass yield ranged between 2.9 and 5.2 t ha^{-1} in cowpea and from 0.95 to 1.5 t ha^{-1} among soybean cultivars. The IT89KD-288 produced significantly the largest vine yield among the 10 legume genotypes investigated. The cowpea genotypes consistently had significantly ($P<0.05$) higher vines than the soybean.

Table 1: Chemical and physical properties of soil (0-15 cm) at the experimental site prior to legume cropping

Soil parameter	Value
pH ($CaCl_2$)	5.40
Org. C (g kg^{-1})	0.80
Total N (g kg^{-1})	0.32
Available P (mg kg^{-1})	1.14
Exchangeable cation (cmol kg^{-1})	
Ca	1.73
Mg	0.23
K	0.12
Na	0.21
Cation exchange capacity (cmol kg^{-1})	5.64
Base saturation (%)	40.60
Particle size distribution	
Sand (g kg^{-1})	792.00
Silt (g kg^{-1})	183.00
Clay (g kg^{-1})	25.00
Textural class	Sandy Loam

Table 2: Effect of cowpea and soybean genotypes on nodule number, above ground biomass and grain yield.

Legume	Cultivars	Biomass yield (kg ha^{-1})	Litter yield (kg ha^{-1})	Nodule number (No plant $^{-1}$)	Grain yield (kg ha^{-1})
Cowpea	IT 88D- 867-11	3100.00bc	681.30bc	5.67f	1789.60a
	IT 89KD- 288	5266.70a	642.90bc	11.33b	96.30c
	IT 90K- 372- 1 - 2	3200.00bc	1239.70a	8.33cdef	1734.80a
	IT 90K-82-2	2900.00c	508.60c	7.00efd	1958.50a
	Bahaushe (local)	3566.70b	889.90b	9.33bcd	948.20b
Soybean	TGX 1945-1F	1538.30d	49.80d	14.33a	61.30c
	TGX 1935-3F	1063.40d	28.00d	6.00ef	50.70c
	TGX 1951-3F	946.40d	38.50d	8.67bcde	44.00c
	TGX 1951-4F	1129.30d	55.30d	14.00a	62.30c
	TGX 38-54-KT	1279.60d	55.30d	10.00bc	55.30c
	S E	206.96	106.59	0.86	92.97

For each treatment, values within a column followed by the same letter are not significantly different at $P< 0.05$.

On the whole and irrespective of the legume genotype, the cowpea had significantly the largest biomass yield (Table 3).

Singh *et al*. (1997) reported vine yields of 6.9 and 1.0 t ha^{-1} in IT89KD-252 and IT84S-2246-4 respectively. Only the biomass yields obtained from cowpea genotypes were larger than the 2 t ha^{-1} recommended by Gilbert (1999) and ICRISAT (2000) for better yield response in the following year when residues were returned into the soil. Litter yield in both legume genotypes showed similar trend to those of the biomass yield. The IT90K-372-1-2 genotype, however, had litter yield of 1.2 t ha^{-1}, which was significantly larger than those of the other cowpea and all soybean genotypes. Also between legume varieties, the litter yield in cowpea (0.79 t ha^{-1}) was significantly larger than that of the soybean (0.041 t ha^{-1}) (Table 3). Thus, IT89KD-288 contributed 6.4 t ha^{-1} above ground biomass (including litter) with up to 81.03 kg ha^{-1} N to the soil.

Table 3: The above ground biomass and grain yields as affected by legume type

Legume type	Biomass (kg ha^{-1})	Litter (kg ha^{-1})	Grain (kg ha^{-1})
Cowpea	3606.70a	792.27a	1305.48a
Soybean	1191.40b	41.10b	54.73b

For each treatment, values within a column followed by the same letter are not significantly different at P< 0.05.

Nodulation: All the legume cultivars investigated nodulated ascertaining the success of breeding and their promiscuity, however, the number differed depending on the genotype (Table 4). The nodule number ranged from 5.67 to 14.00 plant^{-1}. The TGX1951-4F and IT89KD-288 genotypes produced the highest nodule number (14 and 11.33 plant^{-1} respectively).

Soybean had significantly higher nodule number than cowpea (Table 5). The number of nodules observed in both legume genotype fell within the range reported by previous workers. Olufajo *et al.* (1988) reported 3 – 34 nodules plant^{-1} in soybean while Yusuf *et al.* (2006) reported a range of 7.4 and 17.1 nodules in cowpea.

Grain yield: In Table 4, the IT90K-82-2 cowpea genotypes had significantly the highest grain yield value of 1.96 t ha^{-1} in all the legume genotypes studied. All the cowpea genotypes recorded significantly larger grain yield than soybean genotypes (Table 4). Soybean grain yield ranged between 0.044 and 0.062 t ha^{-1} in TGX1951-3F and TGX1951-4F respectively and were below the range of between 0.93 and 1.18 t ha^{-1} reported by Singh *et al.* (2003). The highest value obtained in TGX1951-4F did not differ statistically from the other soybean genotypes. On the whole, cowpea produced grain yield of 1.3 t ha^{-1} that was significantly higher than that of soybean (0.041 t ha^{-1}) (Table 5). Cowpea grain yield observed in this study fell within 0.053 and 2.87 t ha^{-1} range as reported by Singh *et al*. (1997).

Biomass and litter nitrogen yield: Biomass N values that ranged from 22.3 (TGX1935-3F) to 30.23 (TGX1945-1F) kg N ha^{-1} were recorded in soybean cultivars (Table 4). On the other hand, cowpea cultivars produced between 33.13 (IT90K-82-2) and 76.6 (IT89KD-288) kg N ha^{-1} biomass nitrogen. Except for IT90K-82-2 that had biomass N value of 33.13 kg N ha^{-1} which did not differ significantly from those of the soybean cultivars, the cowpea cultivars had significantly (P<0.05) higher biomass N contents (Table 4) than soybean.

Results in Table 4 showed that the litter N content ranged between 2.0 and 7.07 kg N ha^{-1} for TGX1951-4F and IT90K-372-1-2 respectively. The Bahaushe and IT90K-372-1-2 had significantly the highest litter N yield than other cultivars. However, Bahaushe litter N yield did not differ statistically from IT89KD-288 genotype. Comparing cowpea and soybean, the biomass and litter N yields (Table 5) of cowpea was significantly (P<0.05) higher than soybean. Except for the IT89KD-288 biomass N (76.6 kg N ha^{-1}) and IT90K372-1-2 litter N (7.07 kg N ha^{-1}) that were higher than the upper limit of the ranges reported by previous workers, the biomass and litter N observed in this work compared favourably with those ranges obtained by the workers. Litter and biomass N ranges of between 2.0 and 6.2 and 28.3 and 54.96 kg N ha^{-1} were reported by Singh *et al.* (2003) and Bala *et al.*(2003) respectively.

Table 4: Above ground and grain N contents, N_2 - fixed, N balance and N H I as influenced by cowpea and soybean cultivars.

Legume	Cultivars	Biomass N (kg ha^{-1})	Litter N (kg ha^{-1})	Grain N (kg ha^{-1})	N_2- fixed (kg ha^{-1})	N balance (kg ha^{-1})	N H I (%)
Cowpea	IT 88D- 867-11	35..47cd	3.53cd	28.50c	35.5cd	7.03cd	40.67b
	IT 89KD- 288	76.60a	4.43bc	1.40e	48.60abc	47.20a	2.00d
	IT - 372- 1 -2	38.20bc	7.07a	27.87c	41.53bcd	13.67bc	36.67b
	IT 90K-82-2	33.13cde	2.67cd	29.30c	32.33d	3.07cde	42.67b
	Bahaushe (local)	46.30b	5.63ab	14.00d	32.83d	18.00b	20.67c
Soybean	TGX 1945-1F	30.23de	2.93cd	60.27a	59.07a	-1.20efd	64.33a
	TGX 1935-3F	22.30e	2.70cd	51.73b	42.27bcd	-9.47f	67.67a
	TGX 1951-3F	24.10de	2.07d	56.33ab	48.27abc	-8.07ef	68.33a
	TGX 1951-4F	25.40de	2.00d	57.73ab	50.77ab	-6.93ef	70.33a
	TGX 38-54-KT	24.10de	2.93cd	53.03ab	47.77abc	-5.3ef	64.67a
	S E	3.44	0.64	2.44	4.16	3.73	2.42

For each treatment, values within a column followed by the same letter are not significantly different at P< 0.05.

Table 5: The effect of legume types on nodule number, biomass and grain N yields.

Legume type	Nodule number (No. plant^{-1})	Vine N (kg ha^{-1})	Litter N (kg ha^{-1})	Grain N (kg ha^{-1})	N_2-fixed (kg ha^{-1})	N balance (kg ha^{-1})	N H I (%)
Cowpea	8.33b	45.94a	4.67a	20.23b	38.16b	17.95a	28.53b
Soybean	10.60a	25.42b	2.53b	55.82a	49.61a	-6.00b	67.07a

For each treatment, values within a column followed by the same letter are not significantly different at P< 0.05.

Grain N yield: Grain N yield in soybean cultivars were significantly higher than those of the cowpea genotypes. Grain N ranged from 1.4 to 29.3 kg N ha^{-1} in cowpea while soybean recorded a narrow range of between 51.73 and 60.27 kg ha^{-1}. The TGX1945-1F significantly had higher grain N yield than other genotypes (Table 4). On the whole, soybean cultivar had significantly higher grain N yield (55.82 kg N ha^{-1}) than the cowpea (20.23 kg N ha^{-1}) cultivars (Table 5). Only the cowpea cultivars accumulated grain N values that were lower than the 51 to 64 kg N ha^{-1} reported by Sanginga *et al.*(2003) and Bala *et al.*(2003) but comparable to the 30.8 to 32.8 kg N ha^{-1} reported by Yusuf *et al.* (2006) for cowpea . The grain N obtained in all the soybean genotypes fell within the range reported by these workers. The soybean cultivars used in this study were thus better in translocating N to the grains than the cowpea genotypes.

N_2 fixation: TGX1945-1F recorded the highest N_2 fixed value of 59.07 kg N ha^{-1} among soybean and cowpea genotypes. This value significantly differed from those obtained in four cowpea genotypes (IT88D-867-11, IT90K-372-1-2, IT90K-82-2 and Bahushe) and the TGX1935.3F (Table 4). The least N_2 fixed (32.83 kg N ha^{-1}) was obtained in IT90K-82-2 but fell within the range (13.9 to 40.3 kg N ha^{-1}) reported for cowpea by Yusuf *et al.* (2006). Soybean on the whole significantly fixed more N than the cowpea (Table 5). The soybean amount of N_2 – fixed fell within the range of those reported by Sanginga, *et al*. (2003) and Osunde, *et al.* (2003) but much lower than 114 – 188 Kg N ha^{-1} reported by Eaglesham, *et al.* (1982). The wide variations probably depend on the differences in maturity, N_2 - fixing capacity of genotypes, native fertility of soil (Sanginga, *et al.*, 1997), the indeginous *Bradirhizobia* spp. and crop management method (Okogun, *et al.*, 2005).

Nitrogen harvest index (N H I) and nitrogen balance: NHI is the proportion of N translocated to the grains. The percentage N H I obtained in all soybean cultivars were significantly ($P<0.05$) higher than those recorded in cowpea. A range of between 64.33 and 70.33 and 2.0 and 42.67 % were obtained from soybean and cowpea cultivars respectively (Table 4). The TGX1945-4F and IT90K-82-2, however, recorded the highest N H I in soybean and cowpea cultivars respectively. All the cowpea cultivars except IT89KD-288 and Bahaushe recorded N H I values that compared favourably with 37 to 41 percent range obtained by Yusuf *et al.* (2006).

The N balance obtained in this study ranged between 3.07 and 47.2 kg N ha^{-1}in cowpea and from - 9.47 to - 1.2 kg N ha^{-1} among soybean cultivars (Table 4). IT89KD-288 significantly produced the largest N balance in all the legume genotypes investigated. Generally, cowpea recorded 19.95 kg N ha^{-1} N balance while that of soybean was – 6.19 kg ha^{-1} (Table 5).

The negative N balances obtained in the entire soybean cultivars in this research were not in agreement with the findings of Sanginga, *et al.* (1997). They reported TGX 1519 – ID and 1660 – 19F having an average of 23 and 48 Kg ha^{-1} N balances and a corresponding NHI values of 47 and 57 %. These NHI values were lower than the range of between 64.33 – 70.33 % obtained in our study. This indicates that larger N was removed by grains of the soybean cultivars used in our study which resulted in the negative N balances observed. However, negative N balances were reported in some soybean varieties by Singh *et al.* (2003). Yusuf *et al.* (2006) also reported soybean cultivars accumulating larger proportion of their total N uptake in the grain thus resulting in negative N balances.

Conclusion and recommendation: All cowpea genotypes produced above ground biomass (vine and litter)that were above the 2 t ha^{-1}expected of legumes to be able to contribute to soil N the following year. Cowpea accumulated up to 81.03 kg N ha^{-1}in their aboveground biomass. Although soybean fixed more N than the cowpea, they recorded negative N balances . The larger grain N and percentage N H I probably resulted from the effectiveness of the soybean genotypes to translocate N to the grains than to the vegetative parts. It is on these account that the cowpea used in our study appears to be better in contributing to soil N in the following year than the soybean. Therefore, a preferable crop for further works.

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