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Benefits of intercropping selected grain legumes with pearl millet in Nigerian Sudan Savannah

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ABSTRACT

Field experiments were conducted in 2010 and 2011 rainy seasons to assess the benefits of intercropping selected grain legumes with *Pennisetum glaucum* L. at the Teaching and Research Farm of the Department of Crop Production, University of Maiduguri, Maiduguri, Nigeria. The treatments consisted of four pearl millet varieties namely SOSAT-C-88, ZATIP, LACRI-9702-IC and EX-BORNO and four legume types namely groundnut (Samnut–14), soybean (TGX–1830-2E), cowpea (IT89KD-288) and bambaranut (Damboa white). Additive sowing row of the trials were laid out in a Split-Split Plot Design with legumes assigned to the main plots and the pearl millet varieties assigned to the sub-plots in 1:1 alternative row arrangement; with three replicates. The results obtained indicates that the number of pods/plant correlated positively with the length of branches at harvest, and the number of branches at harvest. While legume plant height was positively associated with 100 seed weight as well as with the number of branches at harvest. In addition, weight of pods yield/hectare was positively correlated with length of branches at harvest, number of branches at harvest and number of pods/plant. Linear relationship among agronomic parameters revealed that, grain yield/hectare increased with increase in length of branches, number of branches/plant and number of pods/plant. Higher grain yield and monetary advantages were realized for cowpea + millet and groundnut + millet intercrop than the other associations. The legumes were more competitive when grown in association with millet varieties LACRI-9702-IC and SOSAT-C-88, which produced shorter plants. The SOSAT-C-88 realized greater yield advantage, while ZATIP realized greater monetary advantage among the pearl millet varieties. There was mutual cooperation between cowpea + SOSAT-C-88 intercrop as indicated by the greater yield and monetary advantages. Both Grain yields and cash returns were best realized by pearl millet variety SOSAT-C-88 in association with cowpea and groundnut in the Sudan savannah.

INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br] is one of the most important cereals grown in the tropics (Syngenta, 2002). The production ecology of pearl millet and bambaranut intercrop based system extends from latitude 8° to 14° N (Olufajo and Singh, 2008). Pearl millet is widely grown as rain-fed cereal crop in the arid and semi-arid regions of Africa and South Asia. It is a crop of hot and dry climate and can be grown in areas where rainfall is not sufficient (200-600 mm) for cereal-bambaranut intercrop (FAO, 2005). It is believed to have originated from West Africa and was domesticated more than 40,000 years ago (NRC, 2008). It spread from there to East Africa and then to India. Today pearl millet is a

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staple food crop for more than 500 million people in Africa (Ikeorgu, 2003). Pearl millet it is the third major crop in sub-Saharan Africa (SSA) with the major producing countries being Nigeria, Niger, Burkina Faso, Chad, Mali, Mauritania and Senegal in the West and Sudan and Uganda in the East (FAO, 2005). The principal food crops in the savannah of Nigeria are sorghum, millet, maize, cowpea, soybean, bambaranut and groundnut. Walker et al*.* (2004) reported that the semi-arid region occupies the northernmost part of Nigeria and covers about 36% or 33 million hectares of land being sown with millet and bambaranut. Oluwasemire et al. (2003) ranked pearl millet as the most important cereal in the Sahel and Northern Sudan Savannah and the second most important in the Southern Sudan and Northern Guinea Savannah after sorghum and maize. FAO (2012) reported that the annual production was about 10.7 million tons in Nigeria in 2011, and that 9.3 million tons were used directly as food while 4.6 million tons is used as seeds. Both millet and legumes such as cowpea, groundnut, soybean and bambaranut are used as important food crops in the diet of the people in the Savannah and feed for livestock.

The objectives of intercropping in the semi-arid tropics have variously been rationalized with a general view that the practice can produce larger and more dependable yields than those from sole crops (Baker and Yusuf, 1976). Olufajo and Singh (2004) stated that intercropping is primarily practiced as uncertainty precaution against total crop failure. The immediate objectives of farmers are not much of profit maximization, but one of the stability of income. However, the main objectives of the practice are to produces additional crops without much effect on the base crop yield and to obtain higher total economic return (Mkamilo, 2005). The practice of intercropping of cereal and legume crops is based on the hypothesis that the cereal can utilize nitrogen fixed by the legumes (Simpason, 1965). Most of the experiments have shown that non-legume benefits more from the increase in nitrogen supply and there is a net transfer of nitrogen to the non-legume (Walker et al*.,* 2004). The quantity of nitrogen fixed by legume components in cereal and legume intercropping depends on the species, morphology, density of legume mixture, the type of management and competitive abilities of the component crops (Adu-Gyamfi et al., 2007).

Therefore, the study was put in place to assess the benefits of intercropping different legumes with pearl millet when grown in Nigerian Sudan Savannah soils.

MATERIALS AND METHODS

The experiment was conducted during 2010 and 2011 rainfed cropping seasons at the Teaching and Research Farm, Department of Crop Production, Faculty of Agriculture, University of Maiduguri, Nigeria. Maiduguri is located between longitude 11° 50' N and 13° 40' N, and latitude 14' E, and at an altitude of 352 m above sea level (Kowal and Knabe, 1971). It is in the northern fringes of the Sudan Savannah belt of Nigeria. The long rainy season normally lasts from June to September and the average rainfall is 500 mm (Shaib et al., 1997). The soil at the experimental site has been classified as a *Typic Ustipsamment* with Aeolian sandy-loam (Rayer, 1985).

Experimental design and treatments

The trials were laid out in a split plot design with legumes assigned to the main plots and the pearl millet varieties assigned to the sub-plots. The treatments consisted of four improved varieties of pearl millet namely: ZATIP, LACRI-9702-IC, SOSAT-C-88 and EX-BORNO. Seeds of the pearl millet varieties and the legumes were obtained from the seed multiplication Unit of Borno State Agricultural Development Programme (BOSADP, 1993), Maiduguri. Other treatments were grain legumes namely: groundnut (samnut-14), soybean (TGX-1830-2E), cowpea (IT89KD-288) and bambaranut (Damboa white).

Land preparation and sowing of seeds

The land was ploughed and harrowed with tractor driven disc, after which the plots were laid out down and levelled before sowing. The plot size was 5.0 m × 3.0 m (15.0 m^2) and an alley of 2.0 m was allowed between the replicates and there were three replicates, while 1.0 and 2.0 m was allowed between the main plots and sub-plots, respectively. Each legume variety seed was sown at 75 × 25 cm spacing in three separate sole plots for determination of biological and economical efficiencies. [Sole pearl millet] of each variety was added as one of the main plots thus making total of 5 main plots and 4 sub-plots pearl millet variety (1 + 4 = 5). The pearl millet seeds were sown at three seeds in a hole and legumes were sown at two seeds in a hole (Dugje et al., 2009) which were filled into RCBD (Randomized Complete Block Design) designed in factorial split arrangement.

Management of plants in the field

Weeding of the plots was conducted twice at 3 and 6 weeks after sowing (WAS) (Joshua and Gworgwor, 2000) and thinned manually at two WAS for the pearl millet component. Fertilizer was applied at the recommended rate of 60 kg N/ha, 30 kg P_2O_5/ha and 30 kg K_2O/ha (FPDD, 2002) in two split doses. The first dose of 30:30:30 was applied at two WAS, using NPK (15:15:15) and the second dose of 30 kg N/hectare was applied at six WAS using urea (46% N). For the legumes, 50 kg P_2O_5/ha was applied to the sole plots of the legume component in the intercrop using single super phosphate (18% P_2O_5) one week after sowing. The same fertilizers rates and methods of application were adopted for each cropping season.

Data collection

The data from legumes including plant height, number of leaf branches per plant, length of branches were collected three times (at six and nine WAS, and at harvest). Other data collected included the number of pods/plant, pod yield/plant, seed yield, 100 seed weight, fodder yield. In addition, data on monetary value and the advantage of intercropping were assessed using competitive ability and the land equivalent ratio.

Data analyses

Data collected from the experiment were subjected to two-way Analysis of Variance (ANOVA). This was done separately for each year and then combined years. Analysis was run using a Computer Software, Statistix Version 8.0 (Statistix, 2005). Differences between treatments means were compared using the Least Significant Difference (LSD) and Duncan Multiple Range Text (DNMRT) for separation of means for appropriate tables at 5% level of probability. Variations among experimental units were determined using Standard Error (SE).

RESULTS

Effect of millet-legume intercropping on legume performance

Legume growth and development parameters

There were significant differences in legume plant height at six and nine WAS and at harvest (Table 1). In 2010 at six and nine WAS, plant height was significantly ($P<0.01$) higher for soybean and groundnut intercrops than the bambaranut and cowpea. Plant height was significantly ($P<0.01$) lower for cowpea and bambaranut at six and nine WAS compared to the soybean and groundnut intercrop (Table 1). At harvest, soybean significantly ($P<0.01$) produced tallest plants at harvest than the other legumes and the lowest plant height at harvest was produced ($P<0.01$) by bambaranut intercrop. In 2011 the results showed that at six and nine WAS, and at harvest soybean produced significantly ($P<0.001$) greater plant height, while bambaranut intercrop produced the lowest plant height compared to groundnut and cowpea intercrops (Table 1). For the combined mean similar trend was observed, when soybean produced significantly ($P<0.001$) greater plant height at six and nine WAS, and at harvest while bambaranut maintained significantly ($P<0.01$) lower plant height than groundnut or cowpea intercrop (Table 1).

Number of leaf branches at six WAS in 2010 was significantly ($P<0.001$) greater for groundnut than the other legumes. Similarly, cowpea produced significantly ($P<0.001$) greater leaf branches compared to soybean intercrop which significantly ($P<0.001$) produced the lowest number of leaf branches. There was no significant difference in number of leaf branches at nine WAS, and at harvest (Table 2). Relatively higher number of leaf branches were produced by groundnut and bambaranut compared to cowpea and soybean intercrop. Soybean produced fewer leaf branches than the other legumes at nine WAS, and at harvest. In 2011 there was significant difference at six WAS, and at harvest. The number of leaf branches/plant were significantly ($P<0.05$) greater for groundnut than bambaranut, cowpea and soybean intercrop. Soybean grown in association with millet produced the lowest values. Although there was no significant difference in number of branches/plant at nine WAS, groundnut and bambaranut produced relatively higher number of leaf branches compared to the soybean that had lower leaf branches. At harvest, both bambaranut and groundnut produced significantly ($P<0.01$) greater leaf branches compared to cowpea and soybean intercrop that produced significantly ($P<0.01$) lower leaf branches/plant, while the cowpea intercrop produced intermediate leaf branches in both years. For the combined mean, groundnut and bambaranut maintained significantly ($P<0.01$) greater number of leaf branches (Table 2) when compared to soybean intercrop, that produced significantly ($P<0.01$) lower leaf branches/ plant; while the cowpea intercrop produced intermediate leaf branches in both years.

Intercropping significantly affected length of legume branches at three, six and nine WAS and at harvest in 2010 (Table 3). Cowpea produced significantly ($P<0.01$) greater length of branches compared to groundnut and soybean at all dates. Bambaranut grown in association with millet produced significantly ($P<0.01$) lowest length of branches at three WAS, and at harvest (Table 3). At six WAS groundnut, cowpea and soybean intercrops produced significantly ($P<0.01$) greater length of branches compared to bambaranut. In 2011 there was no significant difference in length of branches at three and six WAS. At nine WAS, cowpea produced significantly ($P<0.01$) greater length of branches compared to bambaranut that significantly *(*$P<0.01$*)* produced the lowest length of branches. At harvest, similar trend was observed for cowpea that produced significantly ($P<0.001$) greatest branch lengths than the other

Table 1. Effect of intercropping pearl millet on legume plant height at six and nine weeks after sowing, and at harvest in 2010, 2011 and combined mean.

Intercrop system	Plant height (cm)		
	Six weeks after sowing	Nine weeks after sowing	Harvest
2010			
Millet + Groundnut	26.89	32.22	56.18
Millet + Bambaranut	12.3	22.14	25.14
Millet + Cowpea	14.76	28.20	41.23
Millet + Soybean	31.46	53.19	70.83
SE (±)	0.19	0.30	1.31
LSD (0.05)	0.46	0.74	3.22
2011			
Millet + Groundnut	33.11	47.37	58.14
Millet + Bambaranut	13.34	26.71	20.88
Millet + Cowpea	19.14	30.24	42.80
Millet + Soybean	51.03	66.31	71.86
SE (±)	3.31	1.79	2.32
LSD (0.05)	8.11	4.38	5.69
Combined mean			
Millet + Groundnut	30.00	40.29	57.16
Millet + Bambaranut	12.83	24.42	23.01
Millet + Cowpea	16.95	29.22	42.02
Millet + Soybean	41.38	59.75	71.35
SE (±)	1.90	0.82	1.68
LSD (0.05)	4.18	2.03	4.12

Values for 2010 and 2011 are pooled means of three replicates of four selected legumes and four pearl millet variety intercrops while values for combined mean are pooled means of three replicate of four selected legumes and four pearl millet varieties intercropped for the two years.

Table 2. Effect of intercropping pearl millet on legume number of leaf branches at six and nine weeks after sowing, and harvest at Maiduguri 2010, 2011 and combined mean.

Intercrop system	Number of leaf branches/plant		
	Six weeks after sowing	Nine weeks after sowing	Harvest
2010			
Millet + Groundnut	28.83	38.75	51.67
Millet + Bambaranut	25.25	31.32	44.86
Millet + Cowpea	22.16	29.58	37.46
Millet + Soybean	17.80	24.64	28.27
SE (±)	0.61	1.88	1.35
LSD (0.05)	1.51	NS	NS
2011			
Millet + Groundnut	26.91	31.85	44.48
Millet + Bambaranut	21.27	28.91	34.48
Millet + Cowpea	22.10	26.31	30.00
Millet + Soybean	13.66	19.61	25.43
SE (±)	0.80	1.75	1.73
LSD (0.05)	1.98	NS	4.25
Combined mean			
Millet + Groundnut	27.87	35.08	48.08

Table 2. Contd.

Millet + Bambaranut	23.26	30.02	39.67
Millet + Cowpea	22.13	27.00	33.76
Millet + Soybean	15.73	22.12	26.85
SE (±)	0.62	1.28	0.82
LSD (0.05)	1.52	3.14	2.01

Values for 2010 and 2011 are pooled means of three replicates of four selected legumes and four pearl millet variety intercrops. Values for combined mean are pooled means of three replicate of four selected legumes and four pearl millet varieties intercropped for the two years.
NS, Not significance.

Table 3. Effect of intercropping pearl millet on legume length of branches (cm) at three, six and nine weeks after sowing, and harvest at Maiduguri 2010, 2011 and combined mean.

Intercrop system	Length of branches (cm)			
	Three weeks after sowing	**Six weeks after sowing**	**Nine weeks after sowing**	**Harvest**
2010				
Millet + Groundnut	3.47	7.60	15.85	36.01
Millet + Bambaranut	2.92	5.31	9.54	13.05
Millet + Cowpea	3.91	7.30	40.10	77.25
Millet + Soybean	2.92	7.06	11.56	15.54
SE (±)	0.16	0.33	2.95	3.87
LSD (0.05)	0.44	0.81	7.23	9.49
2011				
Millet + Groundnut	3.66	8.07	16.35	35.90
Millet + Bambaranut	2.96	7.16	9.86	19.33
Millet + Cowpea	4.42	7.59	44.25	79.19
Millet + Soybean	3.34	7.28	10.85	16.96
SE (±)	0.47	0.37	3.75	7.41
LSD (0.05)	NS	NS	9.18	18.13
Combined mean				
Millet + Groundnut	3.37	7.83	16.10	35.95
Millet + Bambaranut	2.94	6.24	9.70	16.22
Millet + Cowpea	4.17	7.45	42.17	78.22
Millet + Soybean	3.13	7.17	11.20	16.25
SE (±)	0.21	0.21	2.17	5.45
LSD (0.05)	0.52	0.53	6.64	13.35

Values for 2010 and 2011 are pooled means of three replicates of four selected legumes and four pearl millet varieties and intercrops. Values for combined mean are pooled means of three replicates of four pearl millet varieties and four selected legumes intercropped for the two years.
NS, Not significance.

selected legumes (Table 3). For the combined mean at three WAS, cowpea produced significantly (P<0.01) greater length of branches than the other treatments, while bambaranut had significantly (P<0.01) lower length of branches (Table 3). At six and nine WAS and at harvest, cowpea grown in association with pearl millet produced significantly (P<0.001) greater lengths of branches compared to groundnut and soybean intercrop. Similarly, bambaranut intercrop with pearl millet produced significantly (P<0.01) the lowest length of branches than the other selected legumes for the combined mean (Table 3).

Yield components and yield

Number of pods/plant was significantly (P<0.001) greater for cowpea compared to groundnut, bambaranut and

Table 4. Effects of intercropping pearl millet on legume number of pods per plant, pod yield per plant(g), seed yield (kg/ha), 100 seed weight (g) and fodder yield/(kg/ha) at Maiduguri 2010, 2011 and combined means.

Intercrop system	No. of pods/plant	Pod yield/plant (g)	Seed yield (kg/ha)	100 Seed weight	Fodder (kg/ha)
2010					
Millet + Groundnut	33.48	7.75	657.83	37.58	658.92
Millet + Bambaranut	23.47	7.53	635.67	59.91	544.08
Millet + Cowpea	64.00	8.90	705.00	35.16	633.08
Millet + Soybean	23.02	7.48	581.42	54.25	576.17
SE (±)	2.96	0.30	29.69	1.74	122.26
LSD (0.05)	7.26	0.74	72.65	4.27	NS
2011					
Millet + Groundnut	15.98	10.56	663.17	39.83	650.08
Millet + Bambaranut	13.38	10.50	404.50	61.00	323.83
Millet + Cowpea	24.38	11.98	667.50	37.08	464.75
Millet + Soybean	16.13	9.23	451.42	54.75	385.17
SE(±)	1.23	0.59	34.16	2.45	38.09
LSD (0.05)	3.01	1.46	83.59	6.00	NS
Combined mean					
Millet + Groundnut	24.73	9.26	660.04	38.76	654.50
Millet + Bambaranut	18.42	8.99	531.33	60.45	433.96
Millet + Cowpea	40.06	10.44	684.08	36.12	548.92
Millet + Soybean	27.70	8.38	509.12	54.50	480.67
SE(±)	1.60	0.35	22.33	1.36	57.76
LSD (0.05)	3.91	0.86	54.64	3.32	141.35

Values for 2010 and 2011 are pooled means of three replicates of four selected legumes and four pearl millet varieties. Values for combined means are pooled means of three replicates of four varieties intercropped with four selected legume intercrops for the two years.
NS, Not significance.

soybean intercrop, while bambaranut and soybean produced significantly (P<0.001) lower number of pods/plant in 2010 (Table 4). In 2011, cowpea produced significantly (P<0.01) greater number of pods/plant compared to groundnut and soybean that had lower number of pods/plant, but the value was greater than bambaranut (Table 4). For the combined mean, cowpea intercrop produced significantly (P<0.001) greater number of pods/plant compared to soybean and groundnut intercrop. Among the selected legumes, bambaranut grown in association with millet produced significantly (P<0.001) lowest number of pods/plant for the combined mean (Table 4). In 2010, cowpea intercropped with pearl millet produced significantly (P<0.001) greater pod yield/plant compared to the other selected legumes, while bambaranut and soybean in association with millet had comparable pod yield/plant (Table 4). In 2011, cowpea produced significantly (P<0.01) greater pod yield/plant in 2011 than soybean. For the combined mean cowpea had greater (P<0.05) pod yield compared to groundnut and bambaranut intercropped with pearl millet. Soybean grown in combination with pearl millet produced (P<0.01) lower pod yield than groundnut and bambaranut treatments.

Seed yield kg/ha weight was significantly (P<0.01) greater for cowpea than the other legumes in 2010 (Table 4). However, groundnut and bambaranut produced comparable seed yield, while soybean intercrop with pearl millet produced significantly (P<0.01) lower seed yield than the other legumes. In 2011, groundnut and cowpea produced significantly (P<0.05) greater seed yield compared to bambaranut and soybean which produced significantly (P<0.05) lower and comparable seed yields (Table 4). For the combined mean, similar trend was observed when groundnut and cowpea significantly (P<0.01) produced higher seed yield compared to bambaranut and soybean. 100 seed weight, was significantly (P<0.001) greater for bambaranut and soybean in 2010 compared to groundnut and cowpea that produced similar and lower seed weights. In 2011, bambaranut produced significantly (P<0.001) greater seed weight compared to cowpea and groundnut that produced significantly (P<0.001) lower 100 seed weight than other treatments (Table 4). For combined mean, bambaranut produced significantly (P<0.01) greater 100 seed weight when grown in combination with pearl millet compared to cowpea and groundnut intercrop (Table 4). Fodder yield was slightly higher for groundnut and

Table 5. Effect of millet variety on legume plant height (cm) at nine weeks after sowing and harvest, number of leaf branches at nine weeks after sowing and harvest and length of branches (cm) at Maiduguri 2010, 2011 and the combined mean.

Legume + Millet variety (cm)	Plant height		Number of leaf branches		Length of branches (cm)	
	9 WAS	Harvest	9 WAS	Harvest	9 WAS	Harvest
2010						
Legume + SOSAT-C-88	36.81	48.48	43.39	50.88	20.55	37.40
Legume + ZATIP	33.67	45.40	36.24	41.19	15.53	31.40
Legume + LACRI-9702-IC	37.29	49.93	45.79	52.00	24.25	40.53
Legume + EX-BORNO	33.98	46.57	38.57	47.20	18.71	33.38
SE (±)	0.90	2.36	1.14	1.58	2.43	4.92
LSD (0.05)	0.74	3.22	3.31	NS	5.03	NS
2011						
Legume + SOSAT-C-88	42.15	48.71	35.66	49.35	20.88	35.59
Legume + ZATIP	40.53	44.71	25.44	39.29	17.19	29.51
Legume + LACRI-9702-IC	43.35	50.28	37.75	54.70	22.28	42.25
Legume + EX-BORNO	40.64	46.72	28.83	39.07	19.17	35.25
SE(±)	1.57	2.31	0.94	1.35	1.99	5.77
LSD (0.05)	NS	NS	NS	NS	NS	NS
Combined mean						
Legume + SOSAT-C-88	39.48	48.60	39.52	50.11	20.71	36.49
Legume + ZATIP	37.01	45.05	30.84	40.24	16.36	30.46
Legume + LACRI-9702-IC	40.32	50.10	41.28	53.35	23.26	41.39
Legume + EX-BORNO	37.31	46.65	33.70	36.38	18.94	34.32
SE (±)	3.45	1.44	2.40	2.50	1.60	3.33
LSD (0.05)	NS	NS	NS	NS	3.19	6.63

Values for 2010 and are pooled means of three replicates of four legumes and four pearl millet varieties. Values for combined means are pooled means of four selected legumes and four pearl millet varieties intercropped for the two years.
NS, Not significance.

cowpea compared to soybean and bambaranut in 2010 and 2011. However, for the combined mean groundnut and cowpea in combination with pearl millet produced significantly (P<0.05) higher fodder yield than bambaranut and soybean (Table 4).

Effect of pearl millet variety on legume component

Legume growth and development parameters

There were significant differences in legume plant height at nine WAS and at harvest in 2010 (Table 5). At nine WAS, legumes grown in association with SOSAT-C-88 or LACRI-9702-IC produced significantly (P<0.001) greater plant height than ZATIP or EX-BORNO. The legume plant height was significantly (P<0.001) lower when the legumes were grown in combination with ZATIP or EX-BORNO intercrop (Table 5). At harvest similar trend was observed, when the legumes produced greater plant height under SOSAT-C-88 or LACRI-9702-IC than the other varieties. The lowest plant height (P<0.001) was produced when the legumes was grown in combination with ZATIP or EX-BORNO (Table 5). In 2011, there was no significant difference in legume plant height, however, relatively greater plant height was observed for the legume in combination with SOSAT-C-88 or LACRI-9702-IC intercrop than EX-BORNO or ZATIP treatments, at nine WAS and at harvest (Table 5). For the combined mean plant height did not significantly differ. However, legumes grown in mixture with SOSAT-C-88 or LACRI-9702-IC promoted legume plant height, while ZATIP or EX-BORNO suppressed legume plant height at nine WAS and at harvest (Table 5). There was a significant difference in number of leaf branches at nine WAS in 2010. Significantly greater (P<0.05) number of leaf branches were produced when legumes were grown in association with LACRI-9702-IC or SOSAT-C-88 intercrop. There was no significant difference in legume number of leaf branches at harvest. Relatively higher leaf branches was observed for legume intercropped with LACRI-9702-IC or SOSAT-C-88, while lower leaf branches were produced by legumes intercropped with ZATIP or EX-BORNO. There was no significant difference in legume number of leaf branches in 2011 and for the combined mean (Table 5). However, relatively

Table 6. Effect of millet variety on legume seed yield (kg/ha) 100 seed weight and fodder yield (kg/ha) in 2010, 2011 and combined mean at Maiduguri.

Millet variety	Seed yield (kg/ha)	100 seed weight (g)	Fodder yield (kg/ha)
2010			
Legume + SOSAT-C-88	674.33	47.50	622.92
Legume + ZATIP	598.43	45.08	561.83
Legume + LACRI-9702-IC	681.17	49.25	632.42
Legume + EX-BORNO	626.00	46.08	604.08
SE (±)	33.92	2.76	73.75
LSD (0.05)	72.65	5.70	NS
2011			
Legume + SOSAT-C-88	581.83	49.91	520.08
Legume + ZATIP	500.42	43.9	370.58
Legume + LACRI-9702-IC	594.08	51.4	467.50
Legume + EX-BORNO	510.25	47.4	465.50
SE(±)	31.33	3.01	36.55
LSD (0.05)	64.68	NS	75.45
Combined mean			
Legume + SOSAT-C-88	620.46	48.71	571.50
Legume + ZATIP	556.25	44.81	466.21
Legume + LACRI-9702-IC	632.29	49.83	545.46
Legume + EX-BORNO	575.58	46.75	534.74
SE (±)	32.59	2.16	52.67
LSD (0.05)	NS	NS	NS

Values for 2010 and 2011 are pooled means of three replicates of four legumes and four pearl millet varieties. Values for combined mean are pooled means of three replicates of four selected legumes and four pearl millet varieties intercropped for the two years.
NS, Not significance.

higher number of leaf branches was produced for legumes grown in association with SOSAT-C-88 or LACRI-9702-IC compared to ZATIP or EX-BORNO varieties.

Length of branches was significantly ($P<0.01$) higher for legumes grown in mixture with SOSAT-C-88 or LACRI-9702-IC varieties compared to the two other varieties.

EX-BORNO or ZATIP grown in association with legumes reduced significantly ($P<0.01$) length of branches of the legumes at 9 WAS in 2010 (Table 5). There was no significant difference in legume length of branches at harvest. LACRI-9702-IC and SOSAT-C-88 allowed relatively higher length of branches for legumes than ZATIP or EX-BORNO. In 2011, there was no significant difference in length of branches at 9 WAS and at harvest, but a trend similar to 2010 was observed. For the combined mean, there was significantly ($P<0.01$) greater length of branches at 9 WAS and harvest, for legumes grown in combination with LACRI-9702-IC or SOSAT-C-88 varieties. Both ZATIP and EX-BORNO significantly ($P<0.01$) promoted lower length of branches for the legumes than SOSAT-C-88 or LACRI-9702-IC at 9 WAS and harvest for the combined mean (Table 5).

Yield and yield components

There was significant effect of pearl millet variety on legume seed yield per hectare in 2010 and 2011. In 2010 seed yield was significantly ($P<0.05$) greater for the legumes grown in association with SOSAT-C-88 and LACRI-9702-IC compared to the other two pearl millet varieties. Significantly, lower ($P<0.05$) seed yield was produced by the legumes when intercropped with ZATIP or EX-BORNO varieties (Table 6). In 2011, the legumes intercropped with LACRI-9702-IC or SOSAT-C-88 produced significantly ($P<0.001$) greater seed yield than the two varieties (Table 6). For the combined mean, there was no significant difference in seed yield, however, legumes grown in mixture with SOSAT-C-88 or LACRI-9702-IC slightly produced superior seed yield compared to legumes intercropped with ZATIP or EX-BORNO (Table 6). The effect of pearl millet variety on legume 100 seed weight, showed that seed weight was slightly heavier for legume intercropped with LACRI-9702-IC or

SOSAT-C-88 in 2010 (Table 6). In 2011, combined mean, had no significant difference in legume 100 seed weight. Values were similar and comparable, except under LACRI-9702-IC where legumes maintained superior 100 seed weight (Table 6). There was no significant difference in legume fodder yield in 2010 and the combined mean in the 2010, the legume grown in associations with SOSAT-C-88 and LACRI-9702-IC produced relatively higher fodder yield compared to the two varieties (Table 6). In 2011, legume grown in associations with SOSAT-C-88 or LACRI-9702-IC produced (P<0.05) higher fodder yield compared to other combinations (Table 6). The result for the combined mean revealed that legume fodder yield was superior under SOSAT-C-88 and LACRI-9702-IC.

Linear relationships among the combined means

The effect of intercropping legume on pearl millet varieties on linear relationship among agronomic parameters for the combined mean of 2010 and 2011 showed that there was significant linear association between length of branches and fodder weight/ha (r=0.74**) and number of branches was positively associated with fodder yield/hectare (r=0.72**) and length of branches at harvest (r=0.60**). Similarly, the number of pods/plant correlated positively with length of branches at harvest (r=0.50*) and number of branches at harvest (r=0.56*) while plant height was positively associated with hundred seed weight (r=0.49*) and positively correlated with number of branches at harvest (r=0.77**). Pod weight yield/ hectare was positively correlated with length of branches at harvest (r=0.63**), number of branches at harvest (r=0.78**) and number pods/plant (r=0.59*) (Table 7).

In 2010, there was significantly (P<0.01) higher seed yield for groundnut × SOSAT-C-88, and cowpea × LACRI-9702-IC interactions compared to soybean × ZATIP or soybean x SOSAT-C-88 among others (Table 8). In 2011 and the combined mean, groundnut or cowpea x SOSAT-C-88 or LACRI-9702-IC produced significantly (*P<0.01*) higher seed yield. Lower seed yield per hectare was produced (P<0.01) by bambaranut or soybean × ZATIP or EX-BORNO in both years and combined mean (Table 8). The significant (P<0.05) interaction effects on fodder yield showed that, superior fodder yields was observed for groundnut grown in combination with each of the four pearl millet varieties in 2011 (Table 8). The lowest (P<0.05) fodder yield was produced by bambaranut or soybean × ZATIP. For the combined mean, groundnut or cowpea grown × SOSAT-C-88 or LACRI-9702-IC produced significantly (P<0.01) higher fodder yield compared to the other treatments. Fodder yield was lower for soybean × ZATIP or EX-BORNO interactions (Table 8). There was significant interaction between legume and millet variety treatments on 100 seed weight in both years and the combined mean (Table 8). Bambaranut × SOSAT-C-88 or EX-BORNO produced significantly (P<0.01) highest 100 seed weight which was similar to soybean x SOSAT-C-88 and LACRI-9702-IC in 2010. Similarly, groundnut and cowpea × ZATIP or EX-BORNO produced significantly (P<0.01) lower 100 seed weight compared to other treatments. In 2011, soybean or bambaranut × LACRI-9702-IC produced significantly (P<0.01) higher seed weight compared to bambaranut or groundnut × EX-BORNO. Significantly (P<0.01) lower seed weight was produced when cowpea was grown in combination with LACRI-9702-IC (Table 8). For the combined mean, significantly (P<0.05) higher seed weight was observed for bambaranut × EX-BORNO and cowpea × SOSAT-C-88 compared to cowpea × EX-BORNO or soybean × SOSAT-C-88 (Table 8). Both cowpea and bambaranut recorded lower seed weight on interaction with EX-BORNO or ZATIP. In 2010 cropping season there was significantly (P<0.01) higher seed yield for groundnut × SOSAT-C-88, and cowpea LACRI-9702-IC interactions compared to soybean × ZATIP or soybean × SOSAT-C-88 among others (Table 8). In 2011 and the combined mean, groundnut or cowpea × SOSAT-C-88 or LACRI-9702-IC produced significantly *(*P<0.01*)* higher seed yield. Lower seed yield per hectare was produced (P<0.01) by bambaranut or soybean × ZATIP or EX-BORNO in both years and combined mean (Table 8). The significant (P<0.05) interaction effects on fodder yield showed that, superior fodder yields was observed for groundnut grown in combination with each of the four pearl millet varieties in 2011. The lowest (P<0.05) fodder yield was produced by bambaranut or soybean × ZATIP. For the combined mean, groundnut or cowpea grown × SOSAT-C-88 or LACRI-9702-IC produced significantly (P<0.01) higher fodder yield compared to the other treatments. Fodder yield was lower for soybean × ZATIP or EX-BORNO interactions (Table 8).

Effect of pearl millet+legume intercropping on relative competitive ability, land equivalent ratio, and monetary advantage

Pearl millet was more competitive when intercropped with cowpea or groundnut in 2010 and 2011 (Table 9). Similarly in 2011, millet had higher competitive ability in millet + cowpea and millet + groundnut. Pearl millet had the least competitive ability when intercropped with soybean in 2010, 2011 and combined mean. Similarly, among the legume intercrops cowpea had the highest competitive ability in both the years and the combined mean while bambaranut was the least competitive among the legumes. The land equivalent ratio of grain yield of pearl millet + legume intercrop was greater for millet +

Table 7. Linear correlation coefficients (r) of agronomic parameters of four legumes intercropped with four pearl millet varieties, combined mean.

Parameter	1	2	3	4	5	6	7
Fodder yield/ha							
100 seed wt.	0.28						
Length branches	0.74**	0.47					
Number branch	0.78**	0.05	0.60*				
Pods/plant	0.45	0.20	0.50*	0.56*			
Plant height	0.07	0.49*	0.12	0.77**	0.44		
Pod yield/ha	0.33	0.06	0.63**	0.78**	0.59*	0.19	

*, Significant (P<0.05); **, significant (P<0.01); values without asterisk (s) have no significant linear correlations. D. F. = 14.

Table 8. Interaction effects of legume + millet intercrop and pearl millet variety on yield components of legume at Maiduguri 2010, 2011 and combined means.

Legume + millet x variety	100 Seed weight			Seed yield kg/ha			Fodder yield kg/ha	
	2010	2011	Comb	2010	2011	Comb	2011	comb
Groundnut × SOSAT	36.66e	43.00b	39.83e	750.00a	656.33a-c	707.17ab	760.00a	712.83a
Groundnut × ZATIP	36.00c	36.33b	36.16e	666.33a-c	582.33b-d	624.3a-c	458.67b-a	589.00a-d
Groundnut × LACRI	40.00de	42.33b	41.16de	713.33a	764.67a	727.50a	713.33a	702.50ab
Groundnut × EX-BO	37.66e	37.66b	37.66e	690.31a-c	649.33a-e	681.33a-c	668.33a	613.67a-c
Bambaranut × SOSAT	63.00a	59.33a	56.16a-c	659.61a-c	413.67ef	536.67de	361.67b-e	447.33a-c
Bambaranut × ZATIP	53.00a-c	38.00a	60.16a-c	581.33bc	380.67ef	481.00e	232.33e	382.67d
Bambaranut × LACRI	61.33a	63.00a	60.50ab	674.67a	443.67d-f	559.17c-e	373.33b-e	477.17a-d
Bambaranut × EX-BO	62.33a	63.66a	62.16a	627.00a-c	380.00f	548.50de	328.00c-e	408.67a-c
Cowpea × SOSAT	33.00e	33.00b	63.00a	717.00ab	715.00ab	706.83ab	487.00bc	556.17a-d
Cowpea × ZATIP	31.33e	39.00b	37.83e	584.00bc	572.33cd	614.83a-d	455.67b-d	510.00a-d
Cowpea × LACRI	42.33c-e	35.66b	36.50e	742.67a	745.67a	722.83ab	499.67b-d	591.00a-d
Cowpea × EX-BO	34.00e	40.33b	34.33e	587.00bc	637.00a-c	595.67b-e	455.67b-d	538.50a-d
Soybean × SOSAT	58.00ab	40.00b	35.83e	570.67c	542.33c-e	535.17de	459.00bc	514.17a-d
Soybean × ZATIP	49.00b-d	56.33a	49.00cd	559.00c	466.33d-f	504.83de	303.33de	383.17d
Soybean × LACRI	60.00ab	64.66a	58.16ab	617.00a-c	422.33de	519.67de	428.67b-d	549.67a-d
Soybean × EX-BO	49.00b-d	58.00a	50.50bc	579.00bc	374.67	476.83e	348.67b-d	475.67a-d
SE (±)	5.53	6.02	4.32	67.86	62.67	65.18	73.11	105.34

Means followed by the same letter in a column are not significantly different based on the Duncan Multiple Range Test (P<0.05). Values for 2010 and 2011 are the pooled means of three replications. Values for combined means are the pooled means of three replications for the two years.
SWT, Seed weight; Comb, combined mean.

Table 9. Effect of intercropping on relative competitive ability, land equivalent ratio (LER) and monetary advantage (₦) of pearl millet + legume intercrop at Maiduguri.

Intercrop system	RCA millet	RCA legume	Total LER	Monetary advantage (₦)
2010				
Millet + Groundnut	0.90	0.44	1.34	170,399.18
Millet + Bambaranut	0.89	0.40	1.29	137,782.53
Millet + Cowpea	0.92	0.56	1.48	229,312.35
Millet + Soybean	0.82	0.42	1.25	186,368.63
2011				

Table 9. Contd.

Millet + Groundnut	0.84	0.65	1.49	391,099.77
Millet + Bambaranut	0.81	0.43	1.24	128,374.13
Millet + Cowpea	0.84	0.66	1.50	214,554.20
Millet + Soybean	0.72	0.50	1.22	110,508.37
Combined mean				
Millet + Groundnut	0.87	0.54	1.41	280,325.52
Millet + Bambaranut	0.85	0.42	1.27	133,078.33
Millet + Cowpea	0.88	0.61	1.49	221,933.28
Millet + Soybean	0.77	0.46	1.23	148,438.50

RCA, Relative competitive ability; LER, land equivalent ratio.

Table 10. Effects of pearl millet variety on relative competitive ability, land equivalent ratio and monetary advantage (₦) of pearl millet + legume intercrop at Maiduguri.

Millet variety + legume	RCA millet	RCA legume	Total LER	Monetary advantage (₦)
2010				
SOSAT-C-88 + Legume	0.74	0.44	1.18	165,997.56
ZATIP + Legume	0.68	0.40	1.08	137,993.22
LACRI-972-IC + Legume	0.60	0.56	1.16	87,782.53
EX-BORNO + Legume	0.73	0.42	1.15	120,227.25
2011				
SOSAT-C-88 + Legume	0.70	0.65	1.35	120,907.79
ZATIP + Legume	0.69	0.43	1.12	158,682.78
LACRI-972-IC + legume	0.57	0.66	1.23	91,303.59
EX-BORNO + Legume	0.65	0.50	1.15	95,178.93
Combined mean				
SOSAT-C-88 + Legume	0.72	0.54	1.26	134,974.41
ZATIP + Legume	0.68	0.42	1.10	143,552.28
LACRI-972-IC + Legume	0.59	0.61	1.20	78,585.56
EX-BORNO + Legume	0.67	0.46	1.13	114,287.53

RCA, Relative competitive ability; LER, land equivalent ratio.

cowpea and millet + groundnut intercrops in both the years and the combined mean, compared to millet + bambaranut and millet + soybean intercrops (Table 9). The grain yield advantage was higher for millet + cowpea and millet + groundnut compared to millet + soybean and millet + bambaranut for the combined mean. The monetary advantage from the pearl millet + legume intercrop was greater for millet + cowpea intercrop (₦ 229,312.35) in 2010 and millet + groundnut (₦ 391,099.77) in 2011 and (₦ 280,325.52) for the combined mean (Table 9). Monetary advantage was higher for millet + groundnut intercrop during the two years compared to millet + cowpea, millet + bambaranut and millet + soybean intercrops. The least monetary advantage was observed for millet + bambaranut in 2010 and combined mean, while millet + soybean had the least advantage in 2011 (Table 9).

Effect of pearl millet variety on relative competitive ability, land equivalent ratio and monetary advantage

The relative competitive ability was greater for SOSAT-C-88 + legume and EX-BORNO + legume intercrop in 2010 (Table 10). The situation was similar in 2011 when SOSAT-C-88 + legume and ZATIP + legume had higher competitive abilities. The combined mean was slightly superior for SOSAT-C-88 + legume intercrops. The competitive ability was higher by about 18-22% for SOSAT-C-88 + legume intercrop compared to the LACRI-9702-IC + legume that had the least competitive ability among the millet varieties. The land equivalent ratio for pearl millet variety + legume intercrop was greater for SOSAT-C-88 in 2010, 2011 and for the combined mean. In addition, in 2010 and 2011 LACRI-9702-IC + legume had greater land equivalent ratio, compared to EX-BORNO + legume or ZATIP + legume intercrop. The variety ZATIP had the least land equivalent ratio in 2010 and 2011 and EX-BORNO for the combined mean (Table 10).

The monetary advantage from the pearl millet variety intercrop was greater for SOSAT-C-88 in 2010 and ZATIP in 2011 and the combined mean (Table 10). The values of monetary advantage range from ₦ 120,907.79 to ₦ 165,997.56 for SOSAT-C-88 and ₦ 137,993.22 to ₦ 158.682.78 for ZATIP compared to LACRI-9702-IC and EX-BORNO that had the lowest values that range between ₦ 78,585.56 to ₦ 91,303.59 for LACRI-9702-IC and N 95,178.83 to ₦ 120,227.25 for EX-BORNO in both years and the combined mean.

DISCUSSION

The linear relationship among agronomic parameters of legume intercropped with pearl millet showed that the growth parameters had significant correlation with the yield components. There was simultaneous increase in plant height, length of branches and number of branches with increase in pod yield/hectare, and fodder yield/ha. Changhani and Odo (2005) reported that higher values of grain yield indicate successful capture of growth resources early during the season. In similar findings by Dugje and Odo (2006a), reported that leaf area index, effective grain filling duration and number of grains are positive contributors towards increase in grain yield legumes. The interaction between pearl millet variety SOSAT-C-88 and cowpea intercrop produced the highest grain yield and this may attributed to greater vegetative and reproductive parameters over the three other varieties. The significantly negative interactions between pearl millet and soybean can be attributed to the ability of crop system to form early canopy, thereby suppressing the lower storey crop as well as capturing more sunlight for photosynthesis (Terao et al., 2010). Higher partial land equivalent ratio was observed for millet - cowpea intercrop and millet -groundnut this confirms the biological advantages from these intercropping systems. The mutual co-operation between SOSAT-C-88 + legume and LACRI-9702-IC + legume intercrop resulted in greater yield advantages when the biological efficiencies are translated in monetary terms.

Conclusion

In this study, intercropping has shown superior biological and economic advantages for the realization of intercropping objectives in the Sudan Savannah. In terms of pearl millet varieties SOSAT-C-88 proved to be the best for intercropping with legumes as it significantly produced superior biological and economic advantages. In terms of legumes, cowpea had the highest grain yield which was higher than other legumes intercropped with pearl millet. This suggests that SOSAT-C-88 + cowpea intercrop is ideal for both staple grain and cash return from pearl millet + legume intercropping system in the Sudan Savannah.

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