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AGRONOMIC PERFORMANCE OF PEARL MILLET (*PENNISETUM GLAUCUM* (L.) R. BR.) VARIETIES INTERCROPPED WITH LEGUMES IN SUDAN SAVANNAH OF NIGERIA

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ABSTRACT

The accumulation of pesticide acethene was determined for freshwater photosynthetic microorganisms, the cyanobacterium *Oscillatoria curviceps*. An extremely rapid accumulation of pesticides acethene was recorded, although accumulation rate was lower for the lowest concentration of pesticides acethene when compared with higher concentrations of pesticide. Other parameters related to the pesticide concentration capacity of this cyanobacterium was also studied. Chlorophyll a, phycobilin pigments, carbohydrate, protein, lipid, amino acid, and pesticide accumulation analysis were performed. Growth was measured in terms of chlorophyll 'a' in all the six days in intervals. In control, growth was well pronounced up to 12 days from the day of inoculation, in other treatments (50,100,150,200 and 250 ppm) there was slight enhancement upto 12th days followed by a lag phase of another 18 days. Carbohydrate, protein, lipid and amino acid in cultures containing pesticides acethene were clearly affected by pesticide accumulation. Pesticide toxicity and microalgae sensitivity were used to determine the effectiveness of the bioaccumulation process and the stability of pesticide removal. *Oscillatoria curviceps* showed higher accumulation capability for this acethene pesticide. This study supports the usefulness of such cyanobacterium *Oscillatoria curviceps*, as a bioremediation technique in freshwater systems polluted with acethene pesticide compound.

Keywords: Acethene, Accumulation, Bioremediation, Cyanobacterium, *Oscillatoria curviceps*

INTRODUCTION

Pearl millet + legume intercropping is one of the dominant cropping system in the Sudan and Sahel savanna zones of West Africa (Baker, 1978; Dugje et al.,2006b). Both pearl millet and legumes play key roles in food security and income generation for the small holder farmers and in sustaining the environment especially in the semi-arid and arid zones. The traditional millet cultivars, which are still widely used in the savanna zones of West Africa, are late maturing and low yielding under intercropping (ICRISAT, 2011). An important consideration in millet + legume intercropping is the choice of appropriate millet variety and agronomic practices given the fast growth rate of pearl millet. In millet + legume intercropping in the Sudan Savanna, early flowering pearl millet varieties have been shown to yield higher than the tall and late maturing ones (Mkamilo, 2005). Similarly, Okigbo and Greenland (2004) found that short and early flowering varieties

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produced higher grain yield than the tall late flowering varieties when intercropped with legumes in the Sahel Zone. The late flowering varieties also reduce legume yield more than the early maturing short statured varieties, indicating that selection of pearl millet varieties and legume cultivar for intercropping should be based on compatibility of the crop components.

Although improved millet varieties have been developed which do not only yield higher than the local cultivars, but also produce quality straw for livestock and stalks for fencing, there is paucity of emperical studies on their performance in association with the commonly cultivated legumes. Henrich, (2013) observed that intercropping short pearl millet varieties with legumes in 1:1 alternate row arrangement was superior to intercropping tall varieties. IIPPS, (2007) reported superior yield of pearl millet + legume intercrop when dwarf pearl millet varieties was grown in associations with legumes.

Therefore, there are opportunities for increasing the productivity of the pearl millet-based system by exploring the compatability between pearl millet varieties and legume crop components. The effects of intercropping selected legumes on growth and yield of pearl millet has been published in a previous paper by Bassi and Dugje (2016). The objective of this paper is to assess the performancet of improved pearl millet varieties in association with the selected legumes as intercrops in a semi-arid environment.

MATERIALS AND METHOD

Field experiments were conducted in 2010 and 2011 rainy seasons at the Teaching and Research Farm of Department of Crop Production, University of Maiduguri (Latitude 11053'N and Longitude 13050'E). Four pearl millet varieties: SOSAT-C-88, ZATIP, LACRI-9702-IC and EX-BORNO were each intercropped with groundnut (Samnut – 14), soybean (TGX – 1830-2E), cowpea (IT89KD- 288) and bambaranut (Damboa white). A split plot design in Randomized Complete Block arrangement was used where the legumes were assigned to mainplot and pearl millet varieties assigned to subplots, and each treatment was replicated three times. Each of the pearl millet varieties was sown at 90 cm x 50 cm while each legume was simultaneously intercropped into the pearl millet 45cm away from each pearl millet row and 25 cm within the row in 1:1 alternate row arrangement. Sole plots of each Pearl millet varieties and legumes were provided to determine the productivity of the system as described by Willey (1979), and Dugje and Odo (2006a).

Land was harrowed with tractor driven disc. Pearl millet seeds were treated with pre-planting fungicides Apron Star (42 WS) at the rate of 5 g of chemical to a kilogram of seeds. Sowing of the pearl millet and legume seeds was done on 6th July, 2010 and 9th July, 2011 respectively, when rains were fully established. Pearl millet seedlings were thinned to 3 plants per stand at 2 weeks after sowing (WAS), while cowpea and groundnut were grown with 2 plants per stand and soybean with 5 plants per stand. The pearl millet component was side-dressed with 30 kg N, 30 kg P2O5 and 30 kg K2O/ha at 2 WAS using NPK (15:15:15). The second dose of 30 kg N/ha was applied at 6 WAS using Urea (46%N). The legume component was side-dressed with 50 kg P2O5/ha (FPDD, 2002), using Single Super Phosphate at 2 WAS. Weeding was conducted manually at 3 and 6 WAS using African hand hoe. The cowpea plots were sprayed twice (at flowering and pod-filling stages) with cypermetrin + dimethoate (30 grams/litre + 250 grams/litre) of water soluble concentrates to control insect pests. Data collected include growth and development, yield and yield components for the pearl millet, while the legumes grain yield/ha (kg) 100-grain weight (g) and fodder yield/ha (kg) were also determined. Relative competitive ability, land equivalent ratio and monetary advantage (Willey, 1979) were the system productivity parameters determined. Grain yield was measured from a net plot of 9.0 m2. Data collected for each year and the combined years were subjected to analysis of variance (ANOVA). Differences between treatment means were compared using Least Significant Difference (LSD) at 5% level of probability.

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Linear relationships among pearl millet agronomic parameters were also calculated using Pearson Correlation ($P < 0.05$).

RESULTS

Pearl Millet Growth and Development Parameters

There was no significant difference in plant height among the pearl millet varieties at 6 and 9 WAS in 2010 and for the combined mean and in 2011 at harvest (Table 1). The results at harvest in 2010 and the combined mean revealed that plant height was significantly (P<0.001) higher for ZATIP and EX-BORNO than SOSAT-C-88 that significantly (P<0.001) produced shorter plants than the other treatments. In 2011, plant height was also significantly higher at 6 and 9 WAS, for ZATIP and EX-BORNO compared to LACRI -9702-IC and SOSAT-C-88. Similar to plant heights, the taller varieties: ZATIP and EX-BORNO produced greater number of leaves per plant than the shorter varieties: SOSAT-C-88 and LACRI-9702-IC (Table 1). In 2010 and 2011, number of leaves/plant were significantly (P<0.001) greater for EX-BORNO and ZATIP compared to SOSAT-C-88 and LACRI-9702-IC- at 9 WAS and at harvest. Number of leaves was also significantly (P<0.05) greater for EX-BORNO and ZATIP than SOSAT-C-88 and LACRI-9702-IC at 9 WAS for the combined mean.

Table 1: Effect of pearl millet variety on plant height of pearl millet at 6, 9 WAS and harvest and number of leaves/plant at 9 WAS and harvest at Maiduguri 2010, 2011 and combined mean

Millet Variety	Plant height			No. of leaves/plant	
	6 WAS	9 WAS	Harvest	9 WAS	Harvest
2010					
SOSAT-C-88	97.45	154.71	268.31	19.0	7.8
ZATIP	97.26	161.62	324.69	19.8	8.5
LACRI-9702-IC	98.75	150.45	275.91	19.1	7.1
EX-BORNO	98.14	161.43	302.42	20.5	8.3
SE (±)	1.76	1.40	7.07	0.45	0.22
LSD (0.05)	NS	2.87	14.44	0.93	0.46
2011					
SOSAT-C-88	85.45	143.68	250.13	18.9	9.3
ZATIP	89.92	147.00	278.11	19.4	10.3
LACRI-9702-IC	82.42	143.21	247.68	18.9	9.1
EX-BORNO	88.47	146.11	267.17	21.0	9.6
SE (±)	1.86	1.34	2.49	0.43	0.51
LSD (0.05)	3.34	2.81	NS	NS	NS
Combined Mean					
SOSAT-C-88	91.45	149.19	259.22	19.0	8.6
ZATIP	93.59	154.31	301.40	19.6	9.0
LACRI-9702-IC	90.59	146.83	261.80	19.0	7.7
EX-BORNO	93.10	153.77	284.79	20.8	8.9
SE (±)	2.17	2.14	6.29	0.30	0.35
LSD (0.05)	NS	4.26	12.51	0.76	NS

NS= Not Significant

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

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Table 2: Effect of pearl millet variety on pearl millet leaf area (cm^2) at 3, 6, 9 WAS and at harvest at Maiduguri 2010, 2011 and combined mean

Millet variety	3 WAS	6 WAS	9 WAS	Harvest
2010				
SOSAT-C-88	133.3	152.1	183.7	136.2
ZATIP	133.0	164.3	190.7	138.0
LCARI-9702-IC	132.3	148.4	169.2	131.9
EX-BORNO	133.4	147.6	175.0	131.3
SE (±)	1.33	1.86	2.62	1.60
LSD (0.05)	NS	3.80	5.36	3.27
2011				
SOSAT-C-88	133.8	150.5	179.4	133.4
ZATIP	134.3	151.3	181.9	135.7
LACRI-9702-IC	134.1	147.3	172.3	132.4
EX-BORNO	135.5	145.6	170.7	131.2
SE (±)	1.27	1.34	2.22	1.47
LSD (0.05)	NS	2.75	4.54	NS
Combined Mean				
SOSAT-C-88	133.7	151.3	181.6	134.8
ZATIP	133.6	157.9	186.3	136.9
LACRI-9702-IC	133.2	147.8	170.8	132.2
EX-BORNO	134.3	146.6	172.8	131.3
SE (±)	0.87	1.67	1.73	1.31
LSD (0.05)	NS	3.33	3.44	2.60

NS= Not Significant

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

Table 3: Effect of pearl millet variety on pearl millet number of tillers per plant at 3, 6 and 9 WAS and number of days to 50% flowering at Maiduguri 2010, 2011 and combined mean

Millet variety	Number of tillers/plant			Number of days to 50% flowering
	3 WAS	6WAS	9WAS	
2010				
SOSAT-C-88	2.5	2.4	2.7	68.9
ZATIP	1.4	2.3	2.5	80.2
LACRI-9702-IC	1.3	2.2	2.4	68.0
EX-BORNO	1.5	2.3	2.6	76.4
SE (±)	0.68	0.34	0.04	0.74
LSD (0.05)	NS	0.07	0.08	1.51

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2011				
SOSAT-C-88	1.3	2.3	3.0	68.0
ZATIP	1.2	2.2	2.7	77.0
LACRI-9702-IC	1.2	2.2	2.7	72.1
EX-BORNO	1.3	2.4	3.0	79.3
SE (±)	0.05	0.09	0.08	0.65
LSD (0.05)	0.16	NS	0.17	1.34
Combined Mean				
SOSAT-C-88	1.9	2.3	2.8	68.8
ZATIP	1.3	2.2	2.6	78.6
LACRI-9702-IC	1.2	2.2	2.5	70.1
EX-BORNO	1.4	2.4	2.8	78.2
SE (±)	0.34	0.06	0.07	0.83
LSD (0.05)	NS	0.12	0.14	1.65

NS= Not Significant

Values of 2010 and 2011 are pooled means of three replicates of four pearl millet varieties and four selected legumes intercrop, while values of combined mean are pooled means of three replicates of four pearl millet varieties and four selected legume intercrops for the two years

Table 4: Effect of pearl millet variety on pearl millet panicle weight (g), panicle length/plant (cm) and panicle diameter at Maiduguri 2010, 2011 and combined mean

Millet variety	Panicle weight (g)	Panicle length/plant	Panicle diameter (cm)
2010			
SOSAT-C-88	29.8	27.4	3.2
ZATIP	29.9	59.0	2.6
LACRI-9702-IC	24.3	24.5	2.8
Ex-BORNO	28.3	33.6	2.6
SE (±)	1.06	2.34	0.09
LSD (0.05)	2.17	4.79	1.19
2011			
SOSAT-C-88	38.1	28.4	3.0
ZATIP	34.0	62.3	2.5
LACRI-9702-IC	30.6	25.4	2.8
Ex-BORNO	32.4	30.4	2.6
SE (±)	1.37	1.13	0.08
LSD (0.05)	NS	2.32	0.17
Combined Mean			
SOSAT-C-88	33.1	27.9	3.1
ZATIP	31.9	60.7	2.8
LACRI-9702-IC	27.5	24.9	2.8
Ex-BORNO	30.4	34.0	2.6
SE (±)	1.54	1.21	0.07
LSD (0.05)	NS	2.40	0.13

NS= Not Significant: Values of 2010 and 2011 are pooled means of three replicates of four pearl millet varieties and four selected legume intercrops, while values of combined mean are pooled means of three replicates of four pearl millet varieties and four selected legume intercrops for the two years

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However, single leaf area was significantly (P<0.01) greater for ZATIP and SOSAT-C-88 compared to EX-BORNO or LACRI-9702-IC across the two seasons (Table 2). This trend was observed at 6 and 9 WAS and at harvest in 2010, 6 and 9 WAS in 2011 and at 6, and 9 WAS and at harvest for the combined mean. Number of tillers/plant was significantly (P<0.05) greater for SOSAT-C-88 than the other varieties at 6 WAS in 2010 (Table 3). At 9 WAS, values were significantly (P<0.001) greater for SOSAT-C-88 and EX-BORNO while ZATIP and LACRI-9702-IC had comparable values. In 2011 and the combined mean, number of tillers were significantly (P<0.05) greater for SOSAT-C-88 and EX-BORNO, than ZATIP and LACRI-9702-IC at 3 and 9 WAS. Number of days to 50% flowering was significantly (P<0.001) delayed for ZATIP and EX-BORNO compared to SOSAT-C-88 and LACRI-9702-IC in 2010 and 2011 and for the combined man. However, SOSAT-C-88 significantly (P<0.01) flowered earlier than the other varieties in 2011(Table 3).

Panicle Characteristics

The two pearl millet varieties: SOSAT-C-88 and ZATIP significantly (P<0.001) produced greater panicle weight than LACRI-9702-IC in 2010 (Table 4). The three varieties: SOSAT-C-88, ZATIP and EX-BORNO hadcomparable values of panicle weight. Although there was no significant differences in 2011 and for the combined mean, SOSAT-C-88 produced heavier panicles compared to ZATIP, EX-BORNO and LACRI-9702-IC, respectively. Panicle length was significantly (P<0.001) higher for ZATIP than EX-BORNO, SOSAT-C-88, and LACRI-9702-IC in 2010, 2011 and the combined mean. The two varieties: SOSAT-C-88 and LACRI-9702-IC significantly (P<0.001) produced shorter panicles, but LACRI-9702-IC produced the shortest panicle among all the varieties. Panicle diameter was also significantly (P<0.001) greater for SOSAT-C-88 compared to LACRI-9702-IC during both years and the combined mean (Table 4).

Yield Components and Grain Yield of Pearl Millet

Grain yield per plant was relatively higher for SOSAT-C-88 and ZATIP compared to LACRI-9702-IC that produced relatively lower value in 2010 (Table 5). In 2011, ZATIP significantly (P < 0.01) produced greater grain yield/plant compared to LACRI-9702-IC and EX-BORNO. The lowest plant yield was produced (P<0.01) by LACRI-9702-IC and EX-BORNO for the combined mean. Number of grains per panicle was significantly (P<0.01) greater for ZATIP and SOSAT-C-88 than LACRI-9702-IC in 2010 (Table 5). The results in 2011 and combined mean was significantly (P<0.01) greater for ZATIP compared to LACRI-9702-IC. The variety LACRI-9702-IC significantly (P<0.01) produced lower number of grains per panicle during the two years. 1000 grain weight significantly (P<0.05) differed among the pearl millet varieties during both years. The variety SOSAT-C-88 significantly (P<0.05) produced superior grain weight than LACRI-9702-IC and EX-BORNO in 2010, 2011 and the combined mean.

Grain yield per hectare was significantly (P<0.05) greater for SOSAT-C-88 in 2010 and 2011 than LACRI-9702-IC and ZATIP (Table 6). The other promising varieties in 2010 were EX-BORNO and ZATIP. Grain yield per hectare for the combined mean was significantly (P<0.001) higher for SOSAT-C-88 compared to LACRI-9702-IC. Grain yield for SOSAT-C-88 was higher by 9, 16 and 22% than EX-BORNO, ZATIP and LACRI-9702-IC, respectively, for the combined mean (Table 6). Straw yield per plant did not significantly differ among the varieties during both years and the combined mean. However, ZATIP and LACRI-9702-IC produced relatively higher straw yield/plant compared to SOSAT-C-88 and EX-BORNO in 2010 and the combined mean. In 2011 ZATIP and EX-BORNO produced slightly greater straw yield/plant compared to SOSAT-C-88 and LACRI-9702-IC. Harvest index was significantly (P<0.001) higher for ZATIP than EX-BORNO and LACRI-9702-IC in 2010. In 2011, harvest index was significantly (P<0.001) greater for ZATIP and SOSAT-C-88 compared to EX-BORNO and LACRI-9702-IC. The two varieties: LACRI-9702-IC and EX-BORNO produced the lowest harvest indices in 2010, 2011 and for the combined mean.

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Linear Correlation Coefficients (r) among Pearl Millet Agronomic Parameters

The interrelationships among agronomic parameters of pearl millet varieties for the combined mean showed that, there was negative linear correlation between harvest index and number of days to 50% flowering (r = - 051*) (Table 7). However, harvest index was positively correlated with grain yield/ha (r = 0.76**) and grain yield/ plant (r = 0.66**) ,while leaf area at harvest was positively correlated with grain yield /hectare (r = 0.78**), grain yield/plant (r = 0.98**) and harvest index (r = 0.66*)). Number of grains /panicle was negatively associated with number of days to 50% flowering (r = - 0.64**), grain yield /hectare (r = - 0.85**), and grain yield /plant (r = - 0.67**). Number of panicles/plant was positively associated with grain yield/ha (r = 0.92**), grain yield/plant (r = 0.85**) and number of grains/ panicle (r = 0.86**). Number of tillers /plant was positively associated with grain yield/ plant (r = 0.73**), leaf area at harvest (r = 0.81**) and number of grains/panicle (r = 0.76**). Panicle diameter was significantly correlated with harvest index (r = 0.81**) and number of leaves at harvest (r = 0.90**). Similarly, plant height at harvest was positively associated with number of grains /panicle (r = 0.63**) but negatively associated with number of days to 50% flowering (r = - 0.66**) while panicle length was significantly correlated with number of grains/panicle (r = 0.63**) and negatively associated with number of days to 50% flowering (r = - 0.79**).

Table 5: Effect of pearl millet variety on pearl millet grain yield/plant (g), number of grains/panicle and 100 seed yield (g) at Maiduguri 2010, 2011 and combined mean

Millet variety	Grain yield/plant (g)	No. of grains/panicle	1000 seed weight (g)
2010			
SOSAT-C-88	42.9	2287.7	9.2
ZATIP	39.4	2389.5	8.9
LACRI-9702-IC	35.0	2038.9	8.9
EX-BORNO	37.8	2138.5	8.6
SE (±)	1.40	83.64	0.19
LSD (0.05)	NS	170.82	0.39
2011			
SOSAT-C-88	40.2	2232.1	9.5
ZATIP	41.8	2314.0	9.3
LACRI-9702-IC	34.2	2023.5	8.5
EX-BORNO	35.3	2248.0	9.0
SE (±)	1.27	87.16	0.28
LSD (0.05)	2.59	178.02	0.58
Combined mean			
SOSAT-C-88	41.6	2259.9	9.4
ZATIP	40.6	2351.8	9.1
LACRI-9702-IC	34.6	2031.2	8.7
EX-BORNO	36.6	2193.5	8.8
SE (±)	1.41	56.3	0.17
LSD (0.05)	2.80	111.92	0.35

NS= Not Significant: Values of 2010 and 2011 are pooled means of three replicates of four pearl millet varieties and four selected legume intercrops, while values of combined mean are pooled means of three replicates of four pearl millet varieties and for selected legume intercrops for the two years.

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Yield and Yield Components of Legume

Intercropping pearl millet varieties with legumes had significant effect on the performance of the legumes. Grain yield of legumes was significantly greater in 2010 (P<0.05) and 2011 (P<0.001) when the legumes were grown in association with SOSAT-C-88 or LACRI-9702-IC compared to ZATIP or EX-BORNO (Table 8). There was no significant difference in grain yield for the combined mean. However, legumes grown in mixture with SOSAT-C-88 or LACRI-9702-IC slightly produced superior yield compared to legumes intercropped with ZATIP or EX-BORNO for the combined mean. The effect of pearl millet variety on legume 100-grain weight also showed slightly higher values for legumes intercropped with LACRI-9702-IC or SOSAT-C-88 than the taller varieties. Values were similar and comparable, except under LACRI-9702-IC where legumes maintained superior 100-grain weight. There was no significant difference in legume fodder yield in 2010 and the combined mean. Legumes grown in associations with SOSAT-C-88 or LACRI-9702-IC produced relatively higher fodder compared to the other varieties during both years and for the combined mean.

Table 6: Effect of pearl millet variety on pearl millet grain yield (kg/ha), straw yield/plant (g) and harvest index (%) at Maiduguri 2010, 2011 and combined mean

Millet variety	Grain yield (kg/ha)	Straw yield/plant (g)	Harvest index (%)
2010			
SOSAT-C-88	2845.3	48.2	37.3
ZATIP	2457.2	49.5	38.0
LACRI-9702-IC	2351.9	50.4	35.5
EX-BORNO	2555.3	46.5	33.2
SE (±)	186.24	1.90	1.42
LSD (0.05)	380.36	NS	3.01
2011			
SOSAT-C-88	2879.1	50.9	52.5
ZATIP	2474.0	54.2	53.3
LACRI-9702-IC	2333.2	53.1	43.6
EX-BORNO	2707.5	53.9	49.2
SE (±)	190.70	1.87	1.49
LSD (0.05)	359.46	NS	3.05
Combined Mean			
SOSAT-C-88	2862.2	49.5	44.7
ZATIP	2465.6	51.8	45.7
LACRI-9702-IC	2342.5	51.7	39.5
EX-BORNO	2631.4	50.2	41.2
SE (±)	124.7	1.55	2.44
LSD (0.05)	544.62	NS	NS

NS= Not Significant

Values of 2010 and 2011 are pooled means of three replicates of four pearl millet varieties and four selected legume intercrops, while values of combined mean are pooled means of three replicates of four pearl millet varieties and four selected legume intercrops for the two years

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Table 7: Linear correlation coefficient (r) of millet agronomic parametersof four millet + legume intercrops and four pearl millet varieties, combined mean

Parameter	1	2	3	4	5	6	7	8	9	10	11	12
1. Days 50 Flower												
2.Grain yield/ha	0.02											
3. Grain yield/plant	0.11	0.04										
4.Harvest Index	-0.50*	0.76**	0.66**									
5.Leaf Area	0.21	0.78**	0.98**	0.58*								
6.No. grains/panicle	-0.64**	0.85**	0.67**	0.21	0.14							
7.No. leaves/plant	0.01	0.01	0.17	0.31	0.81**	0.03						
8.No. panicles/plant	0.05	0.92**	0.85*	0.03	0.02	0.86**	0.02					
9.No. tillers/plant	0.33	0.23	0.73**	0.04	0.81**	0.70**	0.01	0.14				
10.Panicle diameter	0.25	0.14	0.11	0.81**	0.44	0.19	0.90**	0.03	0.11			
11.Plant height	-0.66**	0.01	0.01	0.25	0.35	0.63**	0.21	0.13	0.21	0.30		
12. Panicle length	-0.79**	0.15	0.02	0.01	0.16	0.77**	0.02	0.62**	0.44	0.05	0.22	
13. Panicle weight	0.32	0.11	0.13	0.14	-0.11	0.01	0.61*	0.26	0.55*	0.01	0.82**	0.15

*Significant (P<0.05) **significant (p<0.01), values without asterisk (s)s have no significant linear correlation, DF=14.

Table 8: Effect of millet variety on legume grain yield (kg/ha) 100 grain weight and fodder yield (kg/ha) in 2010, 2011 and combined mean at Maiduguri

Millet variety	grain yield (kg/ha)	100 grain 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

NS= Not significant: Values for 2010 and are pooled means of three replicates of four legumes and four pearl millet varieties while values for combined means are pooled means of three replicates of four legumes intercrop with four pearl millet varieties intercropped for the two years.

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Table 9: Effects of pearl millet variety on relative competitive ability, land equivalent ratio and monetary advantage (N) of pearl millet + legume intercrop at Maiduguri

Millet Variety + Legume	RCA Millet	RCA Legume	Total LER	Monetary Advantage (N)
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

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 9). 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 grain yield advantage measured as land equivalent ratio for pearl millet variety + legume intercrop was greater for SOSAT-C-88 in 2010, 2011 and for the combined mean. Also, in 2010 and 2011 LACRI-9702-IC + legume had greater grain yield advantage, 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 had the least value for the combined mean (Table 9). The monetary advantage from the crop combinations was greater for SOSAT-C-88 in 2010 and ZATIP in 2011 and the combined mean. The values of monetary advantage ranged from N120, 907.79 to N165, 997.56 for SOSAT-C-88 + legume and N 137,993.22 to N 158.682.78 for ZATIP + legume compared to LACRI-9702-IC + legume or EX-BORNO + legume that had lower values during both years and for the combined mean.

DISCUSSION

Growing pearl millet varieties in association with legumes did not interfere drastically with the performance of the pearl millet varieties as pearl millet remained the dominant component. This is because grain yield per hectare of the pearl millet varieties increased concurrently with leaf area, plant yields and harvest index suggesting low competition from the legume associate. The varietal characteristic exibited by the relatively tall and late matruing ZATIP and EX-BORNO compared to the short statured and relatively early maturing SOSAT-C-88 and LACRI-9702-1C were the major determinats of the relationship between the crop components. Thus the performance of the varieties was determined more by their inherent genetic

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characteristics in canopy expression than by their association with the legume components. The crop architecture, period to maturity and tillering ability determined the relationships between the pearl millet varieties and the legume associate. The elaborate canopy and delayed maturity of ZATIP and EX-BORNO did not allow enough complementarity between these varieties with the legume associates than SOSAT-C-88 or LACRI-9702-IC that was short and early maturing.

Inter-specific competition for growth resources such as water, nutrients and light interception likely affected the performance of the legume components grown with the elaborate and latter maturing pearl millet varieties. Reddy and Willey (1981) agreed that variation in rate of vegetative development, final canopy, and rooting characteristics for extraction of nutrients and water were some of the major factors identified for the success of intercrops. The elaborate vegetative development of ZATIP and EX-BORNO as observed from its superior plant height, number of leaves, leaf area and delayed flowering may have impacted negatively on the variety as it became 'sink limiting' compared to SOSAT-C-88 that exhibited moderate canopy and high tillering ability. The variety LACRI-9702-IC had inelaborate canopy and matured earlier thus probably exhibited 'source limitaion' Cosequently, both panicle diameter and other yield parameters were greater for SOSAT-C-88 than the other varieties. The presences of the legumes interfered with the performance of LACRI-9702-IC as it had the least competitive ability due to the short canopy and early maturity which provided ample complementarity to the legume component at the detriment of the millet variety. Both ZATIP and EX-BORNO produced greater reproductive characters than LACRI-9702-IC, while SOSAT-C-88 produced greater reproductive characters than all the three varieties.

The legumes performed well when they were grown in association with the LACRI-9702-IC or SOSAT-C-88. This agrees with Ntare, (1989) who reported that the shorter structure and less elaborate canopy of these varieties allowed more light penetration and subsequent interception by the legume component understory. ZATIP and EX-BORNO could not avail these complementarity relationships as they probably competed better for growth resources, thus, inhibiting the growth and development of the legumes in both space and time. The efficiency of pearl millet varietal intercropping in this study revealed near mutual co-operation between SOSAT-C-88 and legumes in grain, fodder yields and cash returns. When the objective is to obtain near 'full' yield of pearl millet and near 'full' yield from legume then, growing SOSAT-C-88 with any of the four legumes as intercrops will be ideal in the region.

CONCLUSIONS

Grain yield of legumes was significantly greater when legumes were grown in association with SOSAT-C-88 or LACRI-9702-IC than ZATIP or EX-BORNO. The variety SOSAT-C-88 + legume association had the highest relative competitive ability and grain yield advantage compared to the other intercrop combinations. The gross monetary returns were also highest for pearl millet variety SOSAT-C-88 and ZATIP grown in association with each of the legumes. Grain and fodder yields can be optimized by growing pearl millet variety SOSAT-C-88 in association with any of the four legumes such as cowpea, groundnut, bambarranut or soybean, while monetary returns can be optimized by intercropping SOSAT-C-88 or ZATIP with any of the legumes in the Sudan savanna region.

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