

# Agronomic performances of pearl millet (*Pennisetum glaucum* L.) R. Br.) varieties intercropped with legumes in Sahelian Savanna of Nigeria

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**Abstract.** A field experiment was conducted at Teaching and Research Farm of Department of Crop Production, under Faculty of Agriculture, University of Maiduguri, during 2010 and 2011 rainy season. Four pearl millet varieties: V1=SOSAT-C-88, V2=ZATIP, V3=LACRI-9702-IC and V4=EX-BORNO was intercropped with Groundnut (Var. Samnut – 14), Soybean (Var.TGX – 1830-2E), Cowpea (Var.IT89KD - 288) and Bambaranut (Var. Damboa white) each with 1:1 alternate row arrangement. The results revealed that, plant height, number of leaves per plant and number of days to flowering were significantly higher for varieties ZATIP (V2) and EX-BORNO(V4) than SOSAT-C-88 (V1) or LACRI-9702-1C (V3). Single leaf area was higher for SOSAT-C-88 (V1) and ZATIP (V2), while number of tillers per plant was higher for SOSAT-C-88 (V1) than the other varieties. Grain yield per plant<sup>-1</sup> and harvest index (%) were significantly higher for SOSAT-C-88 (V1) and ZATIP (V2), while grain yield per ha<sup>-1</sup> and 1000 grain weight (g) were significantly higher for SOSAT-C-88 (V1) than the other varieties. Grain yield per ha<sup>-1</sup> was positively correlated with harvest index (%) ( $r = 0.76^{**}$ ), leaf area ( $r = 0.78^{**}$ ), grain yield/panicle ( $r = 0.85^{**}$ ) and number of panicles/plant ( $r = 0.92^{**}$ ). Grain yield of legumes was significantly greater when grown in association with SOSAT-C-88 (V1) or LACRI-9702-IC (V3) than ZATIP (V2) or EX-BORNO (V4). The variety SOSAT-C-88 (V1) + 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 cowpea, groundnut, bambaranut or soybean, while monetary returns can be optimized by intercropping SOSAT-C-88 (V1) or ZATIP (V2) with any of the legumes in the Sudan savannah region.

**Keywords:** Pearl millet, legumes, intercropping, grain yield.

## INTRODUCTION

Intercropping pearl millet and legume is one of 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 and 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 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 empirical 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. IAPPS (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 compatibility 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 performance of improved pearl millet varieties in association with the selected legumes as intercrops in a semi-arid environment.

## MATERIALS AND METHODS

Two field experiments were conducted in consecutive rainy seasons 2010 and 2011 at Teaching and Research Farm, Department of Crop Production under University of Maiduguri, Nigeria. The geographic coordinates of the research studied area were located between 11°53'N Latitude and 13°50'E Longitude. Four pearl millet varieties: V1 = SOSAT-C-88, V2 = ZATIP, V3 = LACRI-9702-IC and V4 = EX-BORNO were each intercropped with Groundnut (Var. Samnut – 14), Soybean (Var. TGX – 1830-2E), Cowpea (Var. IT89KD - 288) and Bambaranut (Var. Damboa white). 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 × 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).

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 6<sup>th</sup> July, 2010 and 9<sup>th</sup> 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 stand and soybean with 5 plants stand. The pearl millet component was side-dressed with 30 kg N, 30 kg P<sub>2</sub>O<sub>5</sub> and 30 kg K<sub>2</sub>O/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 P<sub>2</sub>O<sub>5</sub>/ha (FPDD, 2012), 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 tons<sup>-1</sup> 100-grain weight (g) and fodder yield tons<sup>-1</sup> 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 m<sup>2</sup>. 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. 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

**Table 1.** Plant height (cm), and number of leaves plant<sup>-1</sup> of different pearl millet varieties as influenced by intercropping with different legumes at 6, 9 WAS and harvest at Maiduguri University of during 2010, 2011 and combined mean.

| Millet variety       | Plant height |        |         | No. of leaves/plant |         |
|----------------------|--------------|--------|---------|---------------------|---------|
|                      | 6 WAS        | 9 WAS  | Harvest | 9 WAS               | Harvest |
| <b>2010</b>          |              |        |         |                     |         |
| 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    |
| <b>2011</b>          |              |        |         |                     |         |
| 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      |
| <b>Combined mean</b> |              |        |         |                     |         |
| 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.

than SOSAT-C-88 and LACRI-9702-IC at 9 WAS for the combined mean.

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 mean. 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 had comparable 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

**Table 2.** Leaf area (cm) of different pearl millet varieties as influenced by intercropping with different legumes at 3, 6, 9 WAS and harvest at Maiduguri, University of during 2010, 2011 and combined mean.

| Millet variety       | 3 WAS | 6 WAS | 9 WAS | Harvest |
|----------------------|-------|-------|-------|---------|
| <b>2010</b>          |       |       |       |         |
| SOSAT-C-88           | 133.3 | 152.1 | 183.7 | 136.2   |
| ZATIP                | 133.0 | 164.3 | 190.7 | 138.0   |
| LACRI-9702-IC        | 132.3 | 148.4 | 169.2 | 131.9   |
| EX-BORNO             | 133.4 | 147.6 | 175.0 | 131.3   |
| SE ( $\pm$ )         | 1.33  | 1.86  | 2.62  | 1.60    |
| LSD (0.05)           | NS    | 3.80  | 5.36  | 3.27    |
| <b>2011</b>          |       |       |       |         |
| 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 ( $\pm$ )         | 1.27  | 1.34  | 2.22  | 1.47    |
| LSD (0.05)           | NS    | 2.75  | 4.54  | NS      |
| <b>Combined mean</b> |       |       |       |         |
| 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 ( $\pm$ )         | 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.

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

**Table 3.** Days to 50% flowering and number of tillers per plant of different pearl millet varieties as influenced by intercropping with different legumes at 3, 6 and 9 WAS at Maiduguri University of during 2010, 2011 and combined mean.

| Millet variety       | Number of tillers/plant |      |      | Number of days to 50% flowering |
|----------------------|-------------------------|------|------|---------------------------------|
|                      | 3 WAS                   | 6WAS | 9WAS |                                 |
| <b>2010</b>          |                         |      |      |                                 |
| 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 ( $\pm$ )         | 0.68                    | 0.34 | 0.04 | 0.74                            |
| LSD (0.05)           | NS                      | 0.07 | 0.08 | 1.51                            |
| <b>2011</b>          |                         |      |      |                                 |
| 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 ( $\pm$ )         | 0.05                    | 0.09 | 0.08 | 0.65                            |
| LSD (0.05)           | 0.16                    | NS   | 0.17 | 1.34                            |
| <b>Combined mean</b> |                         |      |      |                                 |
| 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 ( $\pm$ )         | 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.

and EX-BORNO produced the lowest harvest indices in 2010, 2011 and for the combined mean.

#### Linear correlation coefficients (r) among pearl millet agronomic parameters

The relationships 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 ( $r = -0.51^*$ ) (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 ( $r = -0.79^{**}$ ).

#### 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 4.** Panicle weight (g), panicle length<sup>-1</sup> (cm) and panicle diameter (cm) of different pearl millet varieties as influenced by intercropping with different legumes at harvest at Maiduguri, University of during rainy season 2010, 2011 and combined mean.

| Millet variety       | Panicle weight (g) | Panicle length <sup>-1</sup> | Panicle diameter (cm) |
|----------------------|--------------------|------------------------------|-----------------------|
| <b>2010</b>          |                    |                              |                       |
| 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                  |
| <b>2011</b>          |                    |                              |                       |
| 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                  |
| <b>Combined mean</b> |                    |                              |                       |
| 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.

(Table 8). 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 to 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 8). 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 ₦120, 907.79 to ₦165, 997.56 for SOSAT-C-88 + legume and ₦137,993.22 to ₦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.

#### 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 9). 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

**Table 5.** Grain yield<sup>1</sup> (g), number of grains<sup>-1</sup> and 1000 seed yield (g) of different pearl millet varieties as influenced by intercropping with different legumes at Maiduguri, University of during 2010, 2011 and combined mean.

| Millet variety       | Grain yield <sup>1</sup> (g) | No. of grains <sup>-1</sup> | 1000 seed weight (g) |
|----------------------|------------------------------|-----------------------------|----------------------|
| <b>2010</b>          |                              |                             |                      |
| 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                 |
| <b>2011</b>          |                              |                             |                      |
| 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                 |
| <b>Combined mean</b> |                              |                             |                      |
| 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.

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.

## 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 exhibited by the relatively tall and late maturing ZATIP and EX-BORNO compared to the short statured and relatively early maturing SOSAT-C-88 and LACRI-9702-1C were the major determinants of the relationship between the crop components. Thus the performance of the varieties was determined more by their inherent genetic 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

**Table 6.** Grain yield (t ha<sup>-1</sup>), straw yield (g plant<sup>-1</sup>) and harvest index (%) of different pearl millet varieties as influenced by intercropping with different legumes at Maiduguri, University of during 2010, 2011 and combined mean.

| Millet variety       | Grain yield (t ha <sup>-1</sup> ) | Straw yield/plant (g plant <sup>-1</sup> ) | Harvest index (%) |
|----------------------|-----------------------------------|--|-------------------|
| <b>2010</b>          |                                   |  |                   |
| 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              |
| <b>2011</b>          |                                   |  |                   |
| 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              |
| <b>Combined mean</b> |                                   |  |                   |
| 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.

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 limitation'. Consequently, 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



**Table 7.** Linear correlation coefficient (r) of pearl millet + legume agronomic parameters of 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) have no significant linear correlation, DF = 14.

**Table 8.** 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 (₦) |
|-------------------------|------------|------------|-----------|------------------------|
| <b>2010</b>             |            |            |           |                        |
| 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             |
| <b>2011</b>             |            |            |           |                        |
| 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              |
| <b>Combined mean</b>    |            |            |           |                        |
| 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.

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

**Table 9.** 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) |
|------------------------|---------------------|----------------------|----------------------|
| <b>2010</b>            |                     |                      |                      |
| 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 ( $\pm$ )           | 33.92               | 2.76                 | 73.75                |
| LSD (0.05)             | 72.65               | 5.70                 | NS                   |
| <b>2011</b>            |                     |                      |                      |
| 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 ( $\pm$ )           | 31.33               | 3.01                 | 36.55                |
| LSD (0.05)             | 64.68               | NS                   | 75.45                |
| <b>Combined mean</b>   |                     |                      |                      |
| 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 ( $\pm$ )           | 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.

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, bambaranut 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.

## REFERENCES

- Baker EFI (1978).** Mixed cropping in Northern Nigeria: IV. Extended trials with cereals and groundnut, *Exp. Agric.* 16:361-369.
- Bassi JA, Dugje IY (2016).** Effects of intercropping selected legumes on growth and yield of pearl millet in a Nigerian Sudan Savannah. *Res. J. Agric. Environ. Manage.* 5(2):037-047.
- Dugje IY, Odo PE (2006a).** Variety and inter-row spacing influence on Direct Estimation of leaf area index of pearl millet. *J. Sustain. Trop. Agric. Res.* 18:27-32.
- Dugje IY, Odo PE (2006b).** Effects of planting pattern and variety on leaf area index and grain yield of pearl millet intercropped with groundnut. *Niger. J. Exp. Appl. Biol.* 7(1):63-69.
- FPDD (2012).** Fertilizer use and management practice for crop production in Nigeria. Fertilizer Procurement and Distribution Division, Federal Ministry of Agriculture and Rural Development, Abuja Nigeria. p. 47.
- Henrich CW (2013).** Preliminary studies of intercropping combinations based on legumes –Cereals. *Exp. Agric.* 16:29-39.
- IAPPS (2007).** New Sorghum/millet and other grains. IAPPS Newsletter No. 111, March 2007.
- ICRISAT (2011).** Millet Research. In International Crop Research Institute for the Semi-Arid Tropics. Annual Report (2005). Patancheru A.P 562324 71:538-540.
- Mkamilo GS (2005).** Maize + groundnut intercropping in South East Tanzania: farmer's practices and perceptions and intercrop performance *PhD Thesis* Wageningen University, Netherlands.
- Ntare BR (1989).** Evaluation of Cowpea Cultivars for intercropping with Pearl Millet in the Sahelian zone of West Africa. *Field Crops Res.* 20:31-40.
- Okigbo BN, Greenland DJ (1978).** Intercropping system in tropical Africa. In: Multiple cropping (As a Special Publication No. 27(1979):63-101.
- Reddy MS, Willey RW (1981).** Growth and resource use studies in an intercrop of pearl millet and groundnut. *Field Crops Res.* 4:13-24.
- Willey RW (1979).** Intercropping- Its importance and research needs. Competition and yield advantages. *Field Crop Abstracts* 32(2):1-10.