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Productivity of Sorghum/Soyabean Intercrop as Influenced by Cultivar and Row Arrangement in the Northern Guinea Savanna Agro-ecology of Nigeria

Atabo, Josiah Alfa[1] Ogunlela Vincent Babatunde[2] Olufajo Olusoji Olaolu[2] Lawal Abdu Bamidele[2]
1. Department of Crop Production, Kogi State University, PMB 1008, Anyigba. Kogi State. Nigeria
2. Department of Agronomy, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria

Abstract

Field trials were conducted at the Institute for Agricultural Research (IAR) farm, Samaru, Zaria during the 2008, 2009 and 2010 rain-fed seasons to study the performance of sorghum/soyabean intercrop as influenced by cultivar and row arrangement. The treatments tested were made up of two sorghum cultivars (SAMSORG-14 and SAMSORG-17), two soyabean cultivars (TGx 1448-2E and SAMSOY 2) and four crop row arrangements (1SG:1SY, 1SG:2SY, 2SG:1SY and 2SG:2SY, of sorghum : soyabean rows) in factorial combinations. The treatments were arranged in a randomized complete block design and replicated three times. Significantly higher sorghum grain and panicle yields per hectare were recorded at the 2SG:1SY and 1SG:1SY arrangements, respectively than the other crop row arrangements evaluated. The 2SG:1SY row arrangement out-yielded 1SG:2SY, which was the least productive by 85%. The two soyabean cultivars did not differ in yield and yield attributes. However, the two sorghum cultivars had similar grain yield. Intercropped soyabean cultivars had no significant effect on yield attributes of sorghum. Soyabean grain yield was 93.3% higher in 1SG:2SY row arrangement relative to the least value obtained at 2SG:1SY row arrangement.

Key words: Crop row arrangement, cultivars, yield attributes

1.Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is the most widely cultivated cereal crop and very important food crop in the savanna ecological areas (Kowal & Kassam 1978; Ogunlela & Ologunde 1985; Elemo *et al*. 1990; Anon. 1997). Sorghum is a crop of worldwide importance (House 1995) and has the unique ability to produce under harsh environmental conditions. The predominance of cereal-based intercropping systems has been reported in northern Nigeria (Andrews 1972; Abalu 1976; Norman *et al*. 1982; Henriet *et al*. 1997). The review by Elemo *et al*. (1990) show sorghum as being among the most single widespread intercropping practice in the savanna. Intercropping is popular among small-scale farmers in tropical and sub-tropical environments (Wahua & Miller 1978) due to profit maximization, yield stability and diversification of source of nutrition, risk minimization, soil conservation, soil fertility maintenance, weed control, sustenance income and traditional popularity (Evans 1960; Goldsworthy & Watson 1960; Radka 1968; Willey 1979; Fordham 1983; Beets 1990).

Most of the results of maize/grain legume intercropping studies in the tropics suggest that maize depresses yield of intercropped legumes (Koli 1975; Mutsaers 1978; Davis & Garcia, 1983). Reasons attributed for this include inadequate nodulation in cowpea (Wien & Nangju 1976), shading effect (Chui & Shibbles 1983; Eriksen & Whitney 1984), plant architecture and N-nutrition (Ezumah *et al*. 1987). Inadequate rainfall (Fisher 1977) and competition for soil moisture (Agboola & Fayemi 1971) have been reported to result in cowpea yield depression when maize was intercropped with cowpea. The factors that are responsible for the decline in productivity of maize or cereal-cowpea intercropping system may not completely apply to cereal-soyabean intercropping system. Groundnut was reported to be more sensitive to competition with maize than from sorghum (Evans 1960). Results of an experiment conducted by Ahmed & Rao (1982) at 14 locations in seven countries showed that maize-soyabean intercrop appears to be particularly well-suited for small-scale farmers operating at subsistence level with little or no fertilizer. Intercropping generally gave greater combined yields and monetary returns than either crop grown alone. Nigeria is the third world largest producer of sorghum after United States of America (USA) and India with a three-year (2009-2011) average production of 6.44 million tonnes on an area of 4.86 million hectares (Faostat 2011). At the regional level, sub-Saharan Africa is the largest producer and consumer (FAO/WHO 2011). Several investigations have revealed that both sorghum and soyabean while in mixture do not require high nutrient inputs when compared with maize and cowpea. In Nigeria, soyabean crop is rarely given nitrogen fertilizer except a modest dose of it. It is also compatible with existing intercropping systems, especially for maize and sorghum. In most areas, few disease and insect problems have been associated with the crop (Singh & Taylor, 1978). In recent years, research efforts have focused on the improvement and intensification of cereal-legume systems in the moist and dry savannas and West and Central Africa (IITA 2003). These often involved the development of balanced nutrient management strategies, especially P-efficient soyabean varieties with high biological N-fixation resulting in some grain yield increase of over 20 percent. With this development, sorghum-soyabean intercrop could have a substantial economic advantage and therefore, have a very strong appeal to farmers. Olufajo (1995) worked on sorghum/soyabean intercrop in relation to cultivar and planting arrangement and found that intercropping reduced sorghum and soyabean grain yields by 23 percent and 39 percent respectively. Yields of the early and medium-maturing soyabean cultivars were consistently better when sown in the same rows with sorghum compared with sowing in alternate rows. On the other hand, in a study on different planting patterns of sorghum + soyabean intercropping system, Kadam & Baig (2008) reported that sorghum grain yield was highest under a 2:1 planting pattern. In case of yield of soyabean, the 3:6 and 2:1 planting patterns were at par. Tajudeen (2010) evaluated the productivity of sorghum/cowpea intercrop in the savanna agro-ecology and found that the highest grain yield of sorghum in the mixture was obtained at 2S:1C planting arrangement but this was not significantly different from the other planting arrangements. Cowpea yields were generally reduced by intercropping but the extent of yield reduction was minimal in the 1S:2C planting arrangement. Abdur *et al.* (2004) reported that in the two years of study, double row strips planting pattern significantly increased the grain yield of sorghum than single rows and triple row planting patterns. Hamdallah & Ahmad (2010) evaluated the effects of planting patterns (alternate, within row and mixed intercropping) of wheat and bean(*Vicia faba*) and found that there were no significant differences between intercrops grown using different planting patterns. However, in a pearl millet-groundnut intercrop in the Sudan savanna , Dugje & Odo (2003) reported that 1000-grain weight was greater under the 1:0 and 1:1 than 1:2 and 1:3 planting patterns while groundnut 100-seed weight and pod yield per hectare were highest under the 1:3 planting pattern. Dugje & Odo (2003) further reported that 1:2 alternate inter-row arrangement of millet with groundnut was ideal for optimizing spatial complementarity and the consequent realization of greatest grain yield. Mohammed *et al.* (2008) found that cowpea genotypes and row arrangement had no effect on the grain yield and yield attributes of millet. However, millet panicle weight per square metre was significantly lower under the 1:1 and 2:2 row arrangements compared to the 1:2 and 2:4 arrangements in one of the two years while stover yield was higher under the 1:1 row arrangement in both years. Waghmare *et al.* (1982) and Myaka (1995) reported the superiority of paired row arrangement in maize or sorghum + legume intercrops. Karikari *et al.* (1999) found that among the different intercropping systems, the Bambara groundnut + sorghum were the most productive.

Prasad & Brook (2005) reported that soyabean exploited no photosynthetic adaptation to shade and suggested that soyabean could be better grown under maize by increasing between-row spacing of maize from 0.75cm to 1m. This will improve light transmission to the understory and result in higher overall productivity of the intercropping system. Prasad & Brook (2005), further suggested that soyabean germplasms be screened for adaptation to shade. Awal *et al.* (2006) were of the view that the canopy geometry of the subordinate species is likely influenced to a great extent by the shading offered by the dominant canopy but information on the underlying concept is still lacking. Significant yield reductions have been observed in groundnut and cowpea due to shading (Chui & Shibbles, 1983).

A management variable that may influence the efficiency of a cereal/legume intercrop system is component crop density using row arrangement (Ofori & Stern, 1987a). Comparatively, a lot of research has been carried out on cereal/cowpea mixtures. The need to identify sorghum/soyabean combinations for use in the various agro-ecological zones has become necessary in view of their low input requirements. This need is further emphasised as a result of recent global weather changes.

2. **Materials and Methods**

The experiment was conducted during the 2008-2010 rain-fed seasons at the Research Farm of the Institute for Agricultural Research (IAR) Samaru (11° 11'N, 07° 38'E) in the northern Guinea savanna ecological zone of Nigeria to investigate the effects of cultivar and row arrangement on the productivity of intercropped sorghum/soyabean. Row-intercropping system involving two sorghum cultivars namely SAMSORG-14 and SAMSORG-17 with two soyabean cultivars (SAMSOY 2 and TGx-1448-2E) at four intercrop row arrangement patterns (1:1, 1:2, 2:1, and 2:2 SG:SY) were tested with all possible factorial combinations. The randomised complete block design (RCBD) with three replications was used to lay out the experiment. The gross plot size was 45 m^2 (10 ridges) while the net plot comprised 27 m^2 and 18 m^2 for the sole, 1SG:1SY, 1SG:2SY, 2SG:1SY and 2SG:2SY crop row arrangement(s) made up of 6 and 4 inner ridges respectively. Before the commencement of the experiment, soils were collected at random across the experimental field at a depth of 0-15 and 15-30cm with a soil auger, bulked into composite sample and analysed for physico-chemical properties.

SAMSORG-14 released as K.S.V-8 by I.A.R Samaru, is a medium season crop with maturity period of 130-140 days. The crop has potential yield of 2.5-3.0 tonnes per hectare and has a white and large seed (Aba *et al.* 2004*).* The crop is tall (3.1m) and has fairly long open or loose elliptical head and small tan glumes (Obilana 1981 & Olufajo, 1995). SAMSORG-17 was also released by the I.A.R Samaru as K.S.V-3/SK-5912. The crop is long season, semi-tall and tolerant to striga. SAMSORG-17 heads in 130 days and matures between 170 and 175 days. The head is compact and elliptical with bold yellow grains surrounded with brown small glumes (Obilana 1979). The crop has potential yield of 2.5-3.5 tonnes per hectare and is preferred by brewing and livestock industries and confectionary (Aba *et al.* 2004). Both cultivars are photosensitive (Olufajo 1995). SAMSOY 2 released as M216 by I.A.R Samaru in 1983 is a medium (115-129 days) maturing crop. The crop has high shattering resistance (less than 2 percent) and tolerant to endemic insects and pests (Idowu *et al.* 2005). SAMSOY 2 is short and stout with determinate growth habit and bears pods in clusters well above the ground. The seeds are large and yellow (Yayock 1983) and it also possesses yield potential of 1442-2000 kg ha^{-1} (Kim *et al.*1994; Idowu *et al.*2005; Amira *et al.* 2013). The TGx 1448-2E cultivar was released in 1992 by National Cereal Research Institute, Badegi (NACRAB 2012). The crop is medium maturing (115-117 days) and high yielding (1584-1829 kg ha^{-1}). TGx 1448-2E has high shattering resistance (less than 2 percent) and tolerant to endemic insect pests and diseases. (Tukamuhabwa *et al.* 2002; Kang *et al.* 1994 ;Tefera 2010; Amira *et al.* 2013).

The experimental field was ploughed, harrowed and ridges were made at 75cm. The inter-row spacing was 75 cm while within row spacing were 25cm and 5cm for the sorghum and soyabean crops respectively. Sowing was done on 25th June, 2nd July and 3rd July in 2008, 2009 and 2010, respectively. The sowing was done manually and simultaneously. At about three weeks after sowing (WAS), the sorghum sole plots were thinned to one plant per hill while the intercrop was thinned to two plants per hill. The soyabean seeds were sown at 5cm on the ridge. The sowing was done manually and simultaneously. Fertilizer was applied at the rates of 64 kgN and 32 kg P_2O_5 (13.965 kg P) for the sorghum crop and 20 kgN and 60 kg P_2O_5 (26.184 kg P) for the soyabean crop. Urea (46% N) and single superphosphate (18% P_2O_5) were used as sources of N and P respectively. Sorghum was side-dressed with equal halves of 64 kgN ha^{-1} at 3 and 6 WAS while the phosphorus was applied at planting. The soyabean component received all the fertilizer by band application at sowing. Hoe weeding was done at 3 WAS while remoulding was at 6 WAS to prevent lodging and suppress weeds. The net plot comprised the six (6) centre rows with an area measuring 6 x 4.5 m (27 m^2) for the sole, 1SG:1SY, 1SG:2SY, 2SG:1SY crop row arrangements, while the four (4) centre rows measuring 6 x 3m (18 m^2) served as net plot for 2SG:2SY crop row arrangement. The net plot area was harvested when the component crops had reached physiological maturity. The harvested heads and pods were air-dried adequately before they were threshed. Data collected for sorghum include panicle length, panicle yield, 1000-grain weight, stover yield and grain yield while for soyabean, number of seeds per plant, pod yield, seed weight per plant and grain yield. The panicle weight per plant, panicle length, number of pods per plant, pod yield per plant and grain weight per plant were obtained by using ten randomly sampled plants from each net plot and the average recorded per plant. The total panicle yield, stover yield and pod yield were determined at harvest in the entire net plot on a scale and converted to kilogram per hectare using 0.555 as conversion factor for the 2:2 row arrangement, while 0.3703 was for the sole,1:1, 1:2 and 2:1 row arrangements.

The data collected was subjected to statistical analysis of variance to test for significance of treatment differences as described by Snedecor & Cochran (1982). The treatment means was partitioned using the Duncan's Multiple Range Test (Duncan 1955).

3.Result

3.1 Panicle length

Shown in table 1 are data on sorghum panicle length as affected by crop cultivar and crop row arrangement in 2008-2010 rainy seasons. There were significant differences in the two sorghum cultivars used with

SAMSORG-14 producing longer panicles compared with SAMSORG-17. Averaged over the years, SAMSORG-14 panicles were by 12.4% longer than those of SAMSORG-17. There was no significant difference in the effect of the two soyabean cultivars on panicle length of sorghum.

Crop row arrangements, had significant effect on sorghum panicle length in 2008 and 2010. The 1SG:1SY crop row arrangement had longer panicle than 2SG:1SY and was at par with the crop row arrangements in 2008. However, in 2010, 1SG:2SY had longer panicles than 2SG:1SY and 2SG:2SY crop row arrangements The combined data showed that 1SG:1SY and 1SG:2SY crop row arrangements which were also similar to 2SG:2SY crop row arrangement, produced significantly longer panicle length relative to 2SG:1SY crop row arrangement. There were no significant interactions for panicle length among the treatment factors.

Table1: Panicle length (cm) of intercropped sorghum plant as influenced by soyabean and crop row arrangement at Samaru, Nigeria in 2008-2010 cropping seasons.

Treatment	2008	2009	2010	Combined
Sorghum cultivar (SG)				
Samsorg-14	39.0a	30.8a	31.0a	33.6a
Samsorg-17	34.8b	26.2b	28.6b	29.9b
SE ±	0.60	0.59	0.42	0.28
Soyabean cultivar (SB)				
TGx 1148 -2E	36.9	28.2	29.5	31.5
Samsoy 2	36.9	28.9	30.1	32
SE ±	0.69	0.59	0.42	0.28
Crop arrangement(CA)				
1SG:1SY	38.5a	29.0	29.6ab	32.4a
1SG:2SY	37.1ab	28.9	31.3a	32.4a
2SG:1SY	35.7b	28.0	29.2b	30.9b
2SG:2SY	36.4ab	28.2	29.1b	31.2ab
SE ±	0.85	0.22	0.59	0.40
Interaction				
SG X SB	NS	NS	NS	NS
SG X CA	N.S	N.S	N.S	N.S
SG X SB X CA	NS	NS	NS	NS

Means followed by the same letter(s) within WAS, year and treatment group are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

3.2 Panicle weight per sorghum plant

The average panicle weight per plant of sorghum as affected by crop row arrangement and crop cultivar during 2008-2010 rain-fed seasons in a sorghum/soyabean intercropping system is presented in table 2. There were significant difference between the two sorghum cultivars in 2008 and 2010 as well as the combined data, when SAMSORG-17 produced significantly higher average panicle weight per plant than SAMSORG-14. The effect of soyabean cultivars on average panicle weight of sorghum in the individual years and combined data were not significant .

With the exception of 2009 experiment, there were significant differences in average panicle weight per plant among the four crop row arrangements examined. The 1SG:2SY row arrangement produced the highest average panicle weight per plant which was significantly higher than 2SG:1SY and 2SG:SY crop row arrangements in 2008 and 2010 respectively. The combined data revealed that 1SG:2SY and 1SG:1SY crop row arrangements produced similar but significantly higher average panicle weight than 2SG:2SY crop row arrangement which in turn was similar with 2SG:1SY crop row arrangement. There were no interactions among the treatment factors on average panicle weight per plant.

Table 2. Panicle weight (g) of intercropped sorghum plant as influenced by soyabean and crop row arrangement at Samaru, Nigeria in the 2008–2010 cropping seasons.

Treatment	2008	2009	2010	Combined
Sorghum cultivar(SG)				
Samsorg -14	100.9b	59.1	60.4b	73.5b
Samsorg -17	121.5a	55.4	72.9a	83.3a
SE ±	4.26	3.13	2.28	2.05
Soyabean cultivar (SB)				
TGx 1148 -2E	110.1	55.9	65.8	77.3
Samsoy- 2	112.3	58.5	67.5	79.4
SE ±	4.26	3.13	2.28	2.05
Crop arrangement(CA)				
1SG:1SY	119.0a	58.8	66.7ab	81.5ab
1SG:2SY	121.0a	62.8	73.3a	85.7a
2SG:1SY	98.0b	54.8	68.3ab	73.7bc
2SG:2SY	106.8ab	52.6	58.3b	72.6c
SE ±	6.02	4.43	4.08	2.90
Interaction				
SG X SB	NS	NS	NS	NS
SG X CA	N.S	N.S	N.S	N.S
SG X SB X CA	NS	NS	NS	NS

Means followed by the same letter(s) within WAS, year and treatment group are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

3.3 Panicle yield per hectare

The effect of crop cultivar and crop row arrangement on sorghum panicle yield in a sorghum/soyabean intercropping system in the 2008-2010 cropping seasons is presented in Table 3. There was significant difference in panicle yield between the two sorghum cultivars in 2009 when SAMSORG-14 produced a significantly higher panicle yield than SAMSORG-17. The combined data showed that the two sorghum cultivars had similar panicle yield. With the exception of 2009 when SAMSOY 2 reduced sorghum panicle yield significantly relative to TGx 1448-2E, soyabean cultivars had no significant effect on panicle yield.

There were significant differences in panicle yield among the four crop row arrangements examined except in 2010. In both 2008 and 2009, 2SG:1SY crop row arrangement had the highest panicle yield followed by 1SG:1SY and 2SG:2SY which were at par while the lowest panicle yield was produced by the 1SG:2SY row arrangement. The combined data revealed that only 1SG:2SY row arrangement gave significantly lower panicle yield than the highest produced by 1SG:1SY crop row arrangement. The interactions among the treatment factors on sorghum panicle were not significant.

3.4 Grain weight per plant

The effect of crop cultivar and crop row arrangement on sorghum grain weight per plant is presented in Table 4. In 2008 and 2010 as well as the combined data, SAMSORG-17 gave significantly higher grain weight per plant than SAMSORG-14. With respect to soyabean cultivars in the intercrop, there was no significant difference in the effect of the two soyabean cultivars on grain weight per plant of sorghum.

Crop row arrangement had significant effect on grain weight per plant in 2008 and 2009 as well as the combined data. In both years, 1SG:2SY crop row arrangement had the highest grain weight per plant but it was at par with 1SG:1SY and 2SG:2SYin 2008 and with 1SG:1SY and 2SG:1SY crop row arrangements in 2009. The least grain weight per plant was produced by 2SG:1SY and 2SG:2SY crop row arrangements in 2008 and 2009 respectively. The combined data revealed that 1SG:2SY crop row arrangement produced significantly higher grain weight per plant than other crop row arrangements except 1SG:1SY crop row arrangement, which in turn was at par with the other two crop row arrangements. There were no significant interactions among the treatment factors on sorghum grain weight per plant in the three years of the experiment.

Table 3: Panicle yield (kgha^{-1}) of intercropped sorghum as influenced by soyabean and crop row arrangement at Samaru, Nigeria in 2008-2010

Productivity of Sorghum/Soyabean Intercrop as Influenced by rain-fed seasons.

Treatment	2008	2009	2010	Combined
Sorghum cultivar (SG)				
SAMSORG-14	2731.6	1685.5a	1302.5	1906.5
SAMSORG-17	2957.2	1113.0b	2030.9	2033.7
SE ±	105.6	58.06	481.72	169.37
Soyabean cultivar (SB)				
TGx 1448 – 2E	2854.4	1518.4a	1330.2	1901
SAMSOY 2	2834.4	1280.2b	2003.1	2039.2
SE ±	105.6	58.06	481.7	169.37
Crop arrangement(CA)				
1SG:1SY	2973b	1455.6b	2811.8	2413.4a
1SG:2SY	2326.8c	1033.6c	993.8	1451.4b
2SG:1SY	3417.8a	1824.1a	1592.6	2278.2a
2SG:2SY	2659.9bc	1283.8b	1268.5	1737.4ab
SE ±	149.34	82.11	678.98	239.35
Interaction				
SG X CA	NS	NS	NS	NS
SG x SB	N.S	N.S	NS	NS
SB X CA	NS	NS	NS	NS
SG X SB X CA	NS	NS	NS	NS

Means followed by the same letter(s) within WAS, year and treatment group are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

3.5 1000-grain weight

*S*hown in table 5 is the effect of crop cultivar and crop row arrangement on 1000-grain weight of sorghum in a sorghum/soyabean intercropping system during the 2008-2010 rainy seasons. There was significant difference in the 1000-grain weight of the sorghum cultivars in each year except 2008. In 2009 and 2010 as well as the combined data, SAMSORG-17 produced heavier seed than SAMSORG-14. Soyabean cultivars had no significant effect on 1000 grain weight of sorghum. Similarly, the effect of crop row arrangement on 1000-grain weight was not significant. The combined data showed no significant differences. The interactions among the treatment factors for 1000-grain weight were not significant.

Table 4: Grain weight (g) of intercropped sorghum as influenced by soyabean and crop row arrangement at Samaru, Nigeria in 2008-2010 cropping seasons.

Treatment	2008	2009	2010	Combined
Sorghum cultivar (SG)				
Samsorg-14	70.7b	36.5	32.9b	46.7b
Samsorg-17	83.7a	30.9	39.1a	51.3a
SE ±	3.57	2.19	1.84	1.53
Soyabean cultivar (SB)				
TGx 1448-2E	76.9	33.4	35.5	48.6
Samsoy-2	77.7	34	36.5	49.4
SE ±	3.57	2.19	1.84	1.53
Crop arrangement(CA)				
1SG:1SY	81.7a	35.1ab	36.0	50.9ab
1SG:2SY	88.3a	37.9a	39.3	55.2a
2SG:1SY	65.1b	33.4ab	35.0	44.5b
2SG:2SY	74.1ab	28.4b	33.7	45.4b
SE ±	5.06	3.10	2.61	2.17
Interaction				
SG X SB	NS	NS	NS	NS
SG x CA	N.S	N.S	N.S	N.S
SG X SB X CA	NS	NS	NS	NS

. Means followed by the same letter(s) within WAS, year and treatment group are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

Table 5:1000- grain weight (g) of intercropped sorghum plant as influenced by soyabean and crop row arrangement at Samaru, Nigeria in 2008-2010 cropping seasons.

Treatment	2008	2009	2010	Combined
Sorghum cultivar (SG)				
Samsorg- 14	35.6	32.4b	30.5b	32.8b
Samsorg- 17	35.8	34.5a	33.5a	34.6a
SE ±	0.78	0.51	0.34	0.32
Soyabean cultivar (SB)				
TGx 1448-2E	35.2	33.5	32.2	33.6
Samsoy 2	36.2	33.4	31.8	33.8
SE ±	0.78	0.51	0.34	0.32
Crop arrangement(CA)				
1SG:1SY	36.2	33.8	32.8	34.3
1SG:2SY	36.5	33.1	31.4	33.7
2SG:1SY	34.8	34.4	31.5	33.6
2SG:2SY	35.3	32.5	32.2	33.3
SE ±	1.11	0.72	0.49	0.46
Interaction				
SG X SB	NS	NS	NS	NS
SG x CA	N.S	N.S	N.S	N.S
SG X SB X CA	NS	NS	NS	NS

Means followed by the same letter(s) within WAS, year and treatment group are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

3.6 Stover yield per hectare

Shown in Table 6 is the effect of crop cultivar and crop row arrangement on stover yield of sorghum in 2008, 2009 and 2010 as well as the combined data in a sorghum/soyabean intercropping system. There was significant difference in the two sorghum cultivars in each of the three years of the experiment, with SAMSORG-14 producing a significantly higher stover yield than SAMSORG-17. Averaged over the years, SAMSORG-14 out-yielded SAMSORG-17 by 29.6 percent. The effect of soyabean cultivars on sorghum stover yield was significant in 2009 when SAMSOY 2 caused a 12.1 percent reduction in stover yield relative to TGx 1448 2E.Also when averaged over the years, SAMSOY 2 caused 20.9 percent reduction in stover yield compared with TGx 1448-2E.

In all the three years of experimentation, 2SG:1SY crop row arrangement produced the highest stover yield followed by 1SG:1SY crop row arrangement which in turn was statistically similar to 2SG:2SY crop row arrangement except in 2009. The least stover yield was obtained from 1SG:2SY crop row arrangement. Similarly, the combined data showed that 2SG:1SY row arrangement produced the highest stover yield followed by 1SG:1SY and 2SG:2SY crop row arrangements, which were at par while 1SG:2SY crop row arrangement gave the least stover yield of sorghum. Averaged over the three years, 2SG:1SY row arrangement increased stover yield by 21.8, 31.4 and 59.2 percent relative to 1SG:1SY, 2SG:2SY and 1SG:2SY crop row arrangements, respectively. The interactions among the treatment factors for this parameter were not significant.

Table 6: Stover yield (kg ha^{-1}) of intercropped sorghum as influenced by soyabean and crop row arrangement at Samaru, Nigeria in 2008-2010 rain-fed seasons.

Treatment	2008	2009	2010	Combined
Sorghum cultivar(SG)				
SAMSORG – 14	9813.00a	4875.4a	4682.5a	6456.9a
SAMSORG – 17	7490.7b	3295.2b	4162.4b	4982.8b
SE ±	338.27	136.76	150.97	128.00
Soyabean cultivar (SB)				
TGx 1448 - 2E	8792.6	4317.9a	4461.8	7056.7a
SAMSOY 2	8511.1	3852.7b	4383.1	5582.6b
SE ±	348.27	136.76	150.97	128.00
Crop arrangement(CA)				
1SG:1SY	8755.5b	4290.1b	4500.9b	5848.9b
1SG:2SY	7214.8c	2862.7d	3345.6c	4474.3c
2SG:1SY	10503.7a	5634.3a	5227.6a	7121.8a
2SG:2SY	8133.3bc	3544.2c	4615.7ab	5434.4b
SE ±	492.53	193.42	213.54	181.02
Interaction				
SG X CA	NS	NS	NS	NS
SG x SB	NS	NS	NS	NS
SB X CA	NS	NS	NS	NS
SG X SB X CA	NS	NS	NS	NS

Means followed by the same letter(s) within WAS, year and treatment group are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT)

3.6 Grain yield per hectare

The effect of crop cultivar and crop row arrangement on the grain yield of sorghum during 2008, 2009 and 2010 rainy seasons and the combined data in a sorghum/soyabean intercropping system is presented in Table 7. There was significant differences in the grain yield of the two sorghum cultivars in 2009 when SAMSORG-14 significantly out-yielded SAMSORG-17 by 60.2 percent. The effect of soyabean cultivars on sorghum grain yield was not significant throughout the years of study. The effect of crop row arrangement on sorghum grain yield was significant in each year and the combined data. In each year, 2SG:1SY crop row arrangement produced the highest grain yield which was only similar to that obtained from 1SG:1SY crop row arrangement

The least grain yield was obtained from 1SG:2SY crop row arrangement in each year except in 2009 when the treatment was at par with 1SG:1SY and 2SG:2SY crop row arrangements. The combined data showed that 2SG:1SY and 1SG:1SY crop row arrangements gave similar but significantly higher grain yield than 2SG:2SY crop row arrangement, which in turn was significantly higher than 1SG:2SY crop row arrangement. Averaged across the three years, grain yield obtained from 2SG:1SY crop row arrangement was 12.7, 50.1 and 85.9 percent higher than that produced by 1SG:1SY, 2SG:2SY and 1SG:2SY crop row arrangements, respectively. The interactions for sorghum grain yield among the treatment factors were not significant.

Table 7: Grain yield (kg ha^{-1}) of intercropped sorghum as influenced by soyabean and crop row arrangement at Samaru, Nigeria in 2008-2010 rain-fed seasons.

Treatment	2008	2009	2010	Combined
Sorghum cultivar (SG)				
SAMSORG – 14	1452	812a	587	950
SAMSORG – 17	1447	507b	623	859
SE ±	84.1	62.2	33.5	63.0
Soyabean cultivar (SB)				
TGx 1448 - 2E	1488	707	601	931
SAMSOY 2	1415	612	609	829
SE ±	84.1	62.2	33.5	63.0
Crop arrangement(CA)				
1SG:1SY	1666ab	765ab	685a	1037a
1SG:2SY	907c	540bc	442c	630c
2SG:1SY	1876a	857a	778a	1170.5a
2SG:2SY	1349b	476c	514b	780b
SE ±	118.9	88.0	47.4	89.2
Interaction				
SG X CA	NS	NS	NS	NS
SG x SB	NS	NS	NS	NS
SB X CA	NS	NS	NS	NS
SG X SB X CA	NS	NS	NS	NS

Means followed by the same letter(s) within WAS, year and treatment group are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT)

3.8 Number of seeds per plant

The effect of crop cultivar and crop row arrangement on number of seeds per plant of two soyabean cultivars in 2008, 2009 and 2010 in a sorghum/soyabean intercropping system is presented in table 8. During each of the three years and the combined data, the two soyabean cultivar, had no significant number of seeds per soyabean plant. Moreover, the effect of intercropped sorghum cultivars was not significant in all the years.

There was significant effect of crop row arrangement on number of seeds per plant of soyabean in one of the three years of experimentation. In 2008, 1SG:1SY row arrangement produced significantly higher number of seeds per plant than 1SG:2SY row arrangement but was statistically similar to 2SG:2SY and 2SG:1SY crop row arrangements. The interactions among the treatment factors were not significant.

Table 8 : Number of seeds per soyabean plant as influenced by sorghum and row arrangement at Samaru during 2008-2010 cropping seasons.

Treatment	2008	2009	2010	Combined
Soyabean cultivar(SB)				
TGX 1448-2E	204.9	55.8	101	121.6
SAMSOY 2	204.0	52.3	95.6	117.3
SE ±	9.55	6.22	10.43	5.15
Sorghum cultivar(SB)				
SAMSORG – 14	211.3	53.3	111.2	125.3.
S AMSORG – 17	197.6	57.9	85.4	113.6
SE ±	9.55	6.22	10.43	5.15
Crop arrangement(CA)				
1SG:1SY	220.9a	60.6	92.2	124.6
1SG:2SY	177.8b	50.3	110.6	112.9
2SG:1SY	200.9ab	61.6	99.9	120.8
2SG:2SY	218.3ab	49.8	90.5	119.50
SE ±	13.51	8.80	14.35	7.28
Interaction				
SV X SB	N.S	N.S	N.S	N.S
SB X CA	N.S	N.S	N.S	N.S
SV X SB X CA	N.S	N.S	N.S	N.S

Means followed by the same letter(s) within WAS, year and treatment group are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

Table 9: Seed weight per plant(g) of soyabean plant as influenced by sorghum and row arrangement during 2008-2010 cropping seasons.

Treatment				
	2008	2009	2010	Combined
Sorghum cultivar(SB)				
TGX 1448-2E	9.1	6.2	11.9	9.1
SAMSOY 2	8.7	6.6	10.8	8.7
SE ±	0.67	0.72	1.02	0.47
Sorghum cultivar (SG)				
SAMSORG – 14	9.0	5.7	12.3	9.0
SAMSORG – 17	8.37	7.1	10.4	8.7
SE ±	0.67	0.73	1.02	0.47
Crop arrangement(CA)				
SG:1SY	8.5	6.8	10.3	8.5
SG1:SY2	10.0	5.6	14.4	10.0
SG2:SY1	8.8	7.2	10.4	8.8
SG2:SY2	8.1	6.0	10.2	8.1
SE±	0.94	1.02	1.45	0.67
Interaction				
SG X SB	N.S	N.S	N.S	N.S
SB X CA	N.S	N.S	N.S	N.S
SG X SB X CA	N.S	N.S	N.S	N.S

Means followed by the same letter(s) within WAS, year and treatment group are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

3.9 Seed weight per plant

Table 9 shows the seed weight per soyabean plant as affected by crop cultivar and crop row arrangement in a sorghum/soyabean intercropping system and the combined data. There was no significant difference in the seed weight per plant of the two soyabean cultivars. Similarly, intercropped sorghum cultivars had no significant effect on seed weight per soyabean plant. The effect of crop row arrangement on seed weight per plant of soyabean was also not significant. The interactions for this parameter among the treatment factors were also not significant.

3.10 Pod yield per hectare

There was no significant difference in the pod yield of the two soyabean cultivars in each year and the combined data (table 10). The effect of sorghum cultivars on pod yield of soyabean was also not significant throughout the period of the trials. Crop row arrangement had significant effect on pod yield of soyabean for the three years of the trials. In 2008, 1SG:1SY crop row arrangement produced the highest pod yield which was only at par with 1SG:2SY crop row arrangement. However, in 2009, 1SG:2SY crop row arrangement produced significantly higher pod yield than 1SG:1SY and 2SG:1SY crop row arrangements. In 2010, 1SG:2SY crop row arrangement produced significantly higher pod yield than the other crop row arrangements that were at par. The least pod yield was produced in each year at 2SG:1SY crop row arrangement. The combined data showed that 1SG:2SY crop row arrangement resulted in significantly higher pod yield per hectare than the remaining crop row arrangements except 1SG:1SY. Averaged across the years, 1SG:2SY crop row arrangement resulted in 14.1, 28.3 and 78 percent higher pod yield relative to 1SG:1SY, 2SG:2SY and 2SG:1SY crop row arrangements, respectively. The interactions among treatment factors on pod yield were not significant.

Table 10: Pod yield (kg ha^{-1}) of intercropped soyabean as influenced by sorghum and row arrangement at Samaru, Nigeria during 2008-2010 rain-fed seasons.

Treatment	2008	2009	2010	Combined
Soyabean cultivar (SB)				
TGx 1448-2E	1755	1592	1556	1634
SAMSOY 2	1890	1439	1474	1601
SE ±	136.1	75.4	110.4	65.2
Sorghum cultivar (SG)				
SAMSORG – 14	1800	1474	1468	1581
SAMSORG – 17	1845	1557	1562	1655
SE ±	135.1	75.4	110.4	65.2
Crop arrangement(CA)				
1SG:1SY	2466.a	1447b	1377b	1763ab
1SG:2SY	2953.ab	1866a	2114a	2011a
2SG:1SY	1217c	1053c	1119b	1130b
2SG:2SY	1554bc	1679ab	1452b	1568b
SE ±	192.4	107.8	156.1	92.2
Interaction				
SG X CA	NS	NS	NS	NS
SG X SB	NS	NS	NS	NS
SB X CA	NS	NS	NS	NS
SG X SB X CA	NS	NS	NS	NS

Means followed by the same letter(s) within WAS, year and treatment group are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

3.11 Grain yield per hectare

The effect of crop cultivar and crop row arrangement on soyabean grain yield per hectare in 2008, 2009 and 2010 rain-fed seasons in a sorghum/soyabean intercropping system and combined data is presented in table 11. The difference in the grain yield of the two soyabean cultivars was significant in 2008 only when SAMSOY 2 produced higher yield relative to TGx 1448-2E by 18.6 percent. The combined data for grain yield was not significant. The effect of intercropped sorghum cultivars on grain yield of soyabean was also not significant throughout the period of the experiment.

Crop row arrangement had significant effect on soyabean grain yield in each year and the combined data. In 2008, 1SG:1SY crop row arrangement had significantly higher grain than 1SG:2SY crop row arrangement which in turn was significantly higher than 2SG:1SY and 2SG:2SY crop row arrangements that were at par. The grain yield in 2009 showed that 2SG:2SY and 1SG:2SY row arrangements produced similar but significantly higher yields than other treatments that were also at par. In 2010 and the combined data, 1SG:2SY crop row arrangement produced significantly higher grain yield than 1SG:1SY and 2SG:2SY crop row arrangements, which in turn produced significantly higher grain yield than the least observed from 2SG:1SY crop row arrangement. Averaged over the three years, grain yield obtained from 1SG:2SY crop row arrangement was 16.3, 23.5 and 93.2 percent higher than that obtained from 1SG:1SY, 2SG:2SY and 2SG:1SY crop row arrangements, respectively. The interactions for grain yield among the treatment factors were not significant.

Table 11 : Grain yield (kg ha^{-1}) of intercropped soyabean as influenced by sorghum and row arrangement at Samaru, Nigeria during 2008-2010 cropping seasons.

Treatment	2008	2009	2010	Combined
Soyabean cultivar (SB)				
TGx 1448-2E	937b	1035	800	924
SAMSOY 2	1111a	862	827	933
SE $\pm$	49.92	69.93	50.26	36.51
Sorghum cultivar (SG)				
SAMSORG – 14	990.1	859	823	891
SAMSORG – 17	1058	1038	803	966
SE $\pm$	49.92	69.93	50.26	36.51
Crop arrangement(CA)				
1SG:1SY	1397a	832b	781b	1002b
1SG:2SY	1141b	1212a	1142a	1165a
2SG:1SY	733c	591b	484c	603c
2SG:2SY	824c	1158a	846b	943b
SE $\pm$	70.60	98.90	71.08	51.63
Interaction				
SG X CA	NS	NS	NS	NS
SG X SB	NS	NS	NS	NS
SB X CA	NS	NS	NS	NS
SG X SB X CA	NS	NS	NS	NS

Means followed by the same letter within WAS, year and treatment group are not significantly different at 5 percent level of probability using Duncan's Multiple Range Test (DMRT).

4.Discussion

The results obtained in the three years have shown that significant differences existed in the average panicle weight per plant, 1000-grain weight and grain weight per plant of the two sorghum cultivars with SAMSORG-17 recording higher values. This observation could be attributed to the leafy nature of SAMSORG-17 coupled with it's semi-dwarf character (Olufajo 1995 & Aba *et al.* 2004) which meant assimilates were efficiently partitioned into the grain rather than for biomass production. Generally, yield characters responded significantly to crop row arrangements. For instance, the panicle yield, panicle length were significantly higher with 1SG:1SY crop row arrangement while 2SG:2SY crop row arrangement had the least panicle weight and grain weight per plant. Both 1SG:1SY and 2SG:1SY crop row arrangements significantly increased grain yield. The observation on grain yield of sorghum agrees with the position of Abdur *et al.* (2004) with respect to double row strip planting pattern. Chiezey *et al.* (2005) working in the same environment (northern Guinea Savanna), where the present study was conducted, were of the view that sorghum grain yield was highest in single alternate row arrangement.

In this experiment, the observations on row arrangements may be attributed to the plant population due to the differences in the crop proportions in the sorghum:soyabean intercrop (50:50, 33:67, 67:33, 50:50) as well as the 2 plants per stand that was maintained in sorghum. In addition, the component crops have different maturity days. SAMSORG-17 and SAMSORG-14 are long duration and medium maturing respectively, while the two soyabean cultivars are medium maturing (Olufajo 1995; Aba *et al.*2004 & Idowu *et al.* 2005). Longer season of SAMSORG-17 means longer grain filling period resulting in heavier grains while the semi-dwarf stature enhances efficient carbohydrate-partitioning (Olufajo 1993). Furthermore, the early harvest of the soyabean cultivars provided SAMSORG-17 more space, water and nutrients particularly from decaying nodules. Baker & Yusuf (1976) had stated that yield advantage would occur if there was a 30 or 40 days maturity difference. In this study, the sorghum and soyabean were sown at the same time but sorghum was harvested 5-6 weeks after soyabean. This development would have provided sorghum with sufficient nutrient and residual moisture. In each of the three years of experimentation, rainfall ended in October (Appendix 1) with 89.0, 151.7 and 82.3mm of rainfall being received that month in 2008, 2009 and 2010 respectively. The time of harvesting soyabean coincided with the reproductive phase of the sorghum which required moisture and nutrient necessary for the grain filling stage of the crop. Martin & Snaydon (1982) found that temporal differences in the use of resource and different use of mineral nutrient were some of the possible reasons for increased yield of beans in beans/barley intercrop as beans were harvested about 3 WAS after barley. Dalal (1977) and Chiezey *et al.* (2004) suggested reduced nutrient stress in the alternate arrangement compared to intercropping within the same row.

The highly significant grain yield per hectare observed in 1SG:1SY and 2SY:1SY inter-row arrangements compared with other arrangements could be due to efficient translocation of assimilates to the developing grains as a result of reduced inter-plant competition. These inter-row arrangements probably ensured that the different sorghum and soyabean growth characters fully exploited the environmental resources (light, water and soil nutrients). In sorghum/cowpea intercrop, Tajudeen (2010) also recommended 2:1 row arrangement in semi arid savanna for higher grain yield of sorghum. Kumar *et al.*(1987) reported 16 percent advantage of maize grain yield in maize/groundnut, cowpea or cotton intercrop in single inter-row relative to double row arrangement. Dugje & Odo (2003) indicated that 1:2 alternate inter-row arrangement of millet with groundnut was ideal for realizing high grain yield.

Soyabean pod and grain yields per hectare were responsive to row arrangement with 1SG:2SY row arrangement resulting in the highest yield. This could be due to the high population of soyabean per unit area as result of the proportion (33:67) of sorghum : soyabean in the intercrop. The implication of this observation is that at this row arrangement, the soyabean yield characters most suitably and adequately utilized environmental resources since there was minimal inter-plant competition. Chiezey *et al.* (2005) reported that pod number, grain yield and pod weight were higher in soyabean in single alternate rows (1:1) with sorghum. Mohta & De (1980) had earlier recommended alternating one row of sorghum with one row of soyabean or two alternate rows of maize with two rows of soyabean for optimum benefits. Similarly, Tsubo & Walker (2004) used radiation transmission model and inferred that alternate intercrop in maize/bean mixture was most efficient in the use of solar energy. Elemo *et al,* (1990) were of the view that differences in crop canopy ensure better utilization of light which translate into better yield. The variations in yield and yield characters in this experiment due to row arrangement further buttress the views of Ofori & Stern (1987b) that component crop density using row arrangement is also a management variable that may influence the efficiency of a cereal/legume intercrop system

5.Conclusion

The study has shown that the productivity of sorghum/soyabean intercrop can be improved by intercropping both cultivars in 2:1or1:2 crop row arrangement for higher yield and yield attributes in sorghum and soyabean respectively. The performance of these cultivars can serve as a basis for the adoption of these crop row arrangements for the northern Guinea savanna of West Africa.

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Appendix 11: Samaru Meteorological Observation in 2008, 2009 and 2010 Rainy Seasons

	Rainfall (mm)			**Temperature (^0C)**						**Relative Humidity (%)**					
Month				**Minimum**			**Maximum**			**10.00H**			**16.00H**		
	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010
January	-	-	-	13.6	14.1	13.4	29.0	33.8	33.8	19.7	14.8	15.7	15.1	8.6	9.0
Febuary	-	-	-	15.7	16.9	17.4	32.0	36.3	37.1	12.7	9.4	11.1	9.4	8.3	8.9
March	-	-	-	19.9	19.6	21.1	38.6	38	37.2	19.5	10.0	18.5	13.8	6.8	5.8
April	72.6	20.3	52.4	29.1	23.2	22.8	57.2	38.4	38.5	34.0	48.7	38.4	23.9	8.2	6.3
May	95.0	85.1	92.9	21.9	22.2	22.7	35.0	35.5	35.4	63.0	60.9	68.2	46.2	8.2	7.0
June	111.7	89.5	158.3	20.9	21	20.6	33.1	33.2	32.6	72.3	71.2	73.1	55.1	8.1	5.3
July	201.3	285	216.8	20.0	20	19.4	30.5	31.3	30.3	79.6	73.4	82.0	68.0	7.4	4.8
August	352.6	439.7	313.4	19.5	20.4	20.1	29.7	30.0	29.8	82.0	80.6	81.9	73.2	5.7	5.5
September	217.5	206.7	211.2	25.5	20.0	20.9	31.4	31.9	31.2	77.1	75.5	78.8	66.0	6.7	5.2
October	89.0	151.7	82.3	18.2	20.2	20.6	33.2	32.8	32.6	58.8	71.0	73.4	51.8	6.6	6.4
November	-	-	-	12.8	14.8	16.2	33.8	32.4	33.7	21.2	37.5	29.1	23.1	8.1	8.7
December	-	-	-	14.6	13.3	12.6	32.1	33.5	31.8	20.8	16.5	17.4	17.8	9.1	8.6
Total	1140.0	1278	1127.3	231.7	225.7	228.0	415.6	91.9	403.9	560.7	569.6	587.6	463.4	91.9	81.5
Mean	**95.0**	**106.5**	**93.9**	**19.3**	**18.8**	**19.0**	**34.6**	**7.7**	**33.7**	**46.7**	**47.5**	**49.0**	**38.6**	**7.7**	**6.8**

Source: Meteorological Unit. Institute for Agricultural Research Ahmadu Bello University, Zaria, Nigeria.