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Assessing the land equivalent ratio (LER) and stability of yield of two cultivars of sorghum (*Sorghum bicolor*L. Moench)-Soyabean (*Glycine max* L. Merr) to Row intercropping system

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Abstract
Field trials were conducted in the Institute for Agricultural Research (IAR) farm, Samaru, Zaria during the 2008, 2009 and 2010 rainy seasons to study the performance of sorghum/soyabean intercrop as influenced by cultivar and row arrangement. The treatments consisted of two sorghum cultivars – SAMSORG-14 and SAMSORG-17, two soyabean cultivars- TGx 1448-2E and SAMSOY 2, four crop row arrangements (1:1, 1:2, 2:1 and 2:2 Sorghum : Soyabean) in factorial combinations. The treatments were arranged in a randomized complete block design. The most stable treatment combination in the trial was SAMSORG-17 intercropped with TGx 1448-2E in 1SG:1SY row arrangement (1.01). All but one intercrop had LER values above unity, thus suggesting a considerable benefit for intercropping sorghum with soyabean.Among the treatment combinations, SAMSORG-17 intercropped with TGx 1448-2E in 1SG:1SY row arrangement produced the highest LER value of 1.40.
Key words: LER, cultivar, crop stability

Introduction

Intercropping is referred to as the growing of two or more crops simultaneously on the same field (Andrews and Kassam, 1976; Fordham; 1983; Lithourgidis *et al*, 2011). The component crops of an intercropping system do not necessarily have to be sown at the same time, but they should be grown simultaneously for a greater part of their growth periods (Ibeawuchi, 2007; Lithourgidis *et al.,*2011). Intercropping is a common feature in the tropical and subtropical regions of the world. Specific intercropping systems have developed over the centuries in the different regions and they are closely adapted to the prevailing ecological and socio-economic conditions (Kurt, 1982; Ofori and Stern, 1987; Ghaffarzadeh, 1999; Ibeawuchi, 2007). Intercropping of cereal and legume crops is especially recognized as a common cropping system throughout tropical countries (Ofori and Stern, 1987) especially among resource-poor farmers which constitute at least 55 percent of world's farmers found mostly in Africa, Asia and Latin America(Ibeawuchi, 2007). Increasing interest in sustainability and environmental concerns has shifted attention back to intercropping as a means of a better utilization of resources while at the same time preserving the environment (Egbe, 2010). Many workers (Andrews, 1972; Abalu, 1976; Norman *et al*., 1982; Henriet *et al*., 1997) have reported that cereal-based intercropping systems are predominant in northern Nigeria. Nigeria is the third world largest producer of sorghum after United States of America (USA) and India (Faostat, 2011)with a three-year (2009-2011) average production of 6.44 million tonnes on an area of 4.86 million hectares.Similarly,in Africa, the three-year (2009-2011) average production data show that Nigeria is the second highest soyabean producing country after South Africa with a production of425,140 tonnes from 375,671 hectares. Several investigations have revealed that both sorghum and soyabean while in mixture do not require high nutrient inputs when compared with maize and cowpea. Expansion of soyabean production area is made feasible by its low labour demand and fertilizer requirement of 26 kg P ha^{-1} and 20 – 30 kg K ha^{-1} (Olufajo, 1986; Chiezey, 1990). 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 and Taylor, 1978).

One of the most important reasons to grow two or more crops together is the increase in productivity per area of land (Ibeawuchi, 2007). There are several criteria to be satisfied in evaluating intercrop experiments, namely, usefulness to the farmer (like crude protein, calories, fat), yield and land use complementarity and intercrop competitiveness (Putnam *et al.,* 1985; Kurt 1982). Crop complementarity of an intercrop may be considered to occur when the intercrop yields are more than the yields obtained from an equivalent land area planted in monoculture (Putnam *et al.*, 1985). The most important index of biological advantage is the relative yield total (RYT) introduced by de Wit and van den Bergh (1965) or land equivalent ratio (LER) proposed by Willey (1979).

Mead and Willey (1980) and Willey (1985), defined LER as the relative land area required as sole crop to produce the same yields as intercropping. LER provides standardized basis so that crops can be added to form combined yields. Comparison between individual LERs (L_A and L_B) can indicate competitive effects. Furthermore, of primary importance, the total LER can be taken as a measure of the yield advantage. For instance, LER of 1.2 indicates a yield advantage of 20 percent (or strictly speaking that 20 percent more land would be required as sole crops to produce the same yield as intercropping).

A management variable that may influence the efficiency of a cereal/legume intercrop system is component crop density using row arrangement (Ofori and Stern, 1987). Steiner (1982), reported that resource utilization may be beneficial but may be differently influenced by genotypes, time of sowing, component population and planting pattern of crop mixtures.
Stability means a reliable food production over years and enhanced diversity of farm (Rao *et al*, 1979). Lithourgidis *et al.,* (2011) observed that stability under intercropping can be attributed to the partial restoration of diversity that is lost under monocropping. Thus diversity from the point of view of intercropping reduces the risk of total crop failure due to extreme weather conditions such as drought, flood and frost. In Nigeria,more soyabean cultivars are being bred and released for production by farmers(Tefera, 2010). The increasing profile of soyabean – based intercropping system in the northern Nigeria coupled with recent global weather changes has necessitated assessing land equivalent ratio of sorghum/soyabean intercropping system as influenced by cultivar and row arrangement.

Materials and methods

Rain-fed field trials were conducted in 2008-2010 cropping seasons at the Research Farm of Institutefor Agricultural Research (IAR) Samaru($11^0 11^1$N, 07^0 38^1E, 686M above sea level) in the northern Guinea savannah ecological zone of Nigeria. The sorghum cultivars used were SAMSORG-14 (KSV-8) and SAMSORG-17(SK5912) while soyabean cultivars were TGx 1448-2E and SAMSOY 2 at four row arrangements (1:1,1:2,2:1,2:2 Sorghum:Soyabean) and the sole crops of both component crops.The experiment was laid out as randomised complete block design (RCBD) with three replications.The gross plot size was $45m^2$ while the net plot size at the middle of the treatment plot was $27m^2$ for the 1:1,1:2,2:1 crop row arrangements while $18m^2$ served as the net plot size for 2:2 row arrangement. Soil samples from the experimental sites (2008 and 2009-2010) were taken from a depth of 0-15cm and 15-30 cm and analysed for physico-chemical properties before applying the recommended fertilizer rate for sorghum (64KgN:13.965KgP) and soyabean (20KgN:26.184KgP)
The tested crops released by IAR (SAMSORG-14, SAMSORG-17 AND SAMSOY 2) and International Institute of Tropical Agriculture(IITA) (TGx 1448-2E) have distinct morphological and physiological features. Normal cultural practice was followed uniformly for all the experimental units. Weeding was done at 3 weeks after sowing (WAS) while remoulding was at 6WAS.
Land equivalent ratio (LER) was determined in order to quantify the land-use efficiency of the intercrop. It was calculated according to the formula by Willey (1985). The crop stability of yield was estimated by first standardising thegrain LER ofboth component crops in the experiment (Oyejolaand Mead,1982). This was done by dividing the highest sole crop in each crop in the three rain-fed seasons. The crop stability was then calculated from the standardised values of the crops on dividing by theyears of experimentation (Odion *et al.,* 2008). It can thus be summarised as follows:

$$CS= \frac{StandardisedLER(a)}{n} + \frac{StandardisedLER(b)}{n}$$

Where a=sorghum b=soyabean n=years of experiment
The data collected was subjected to statistical analysis of variance to test for analysis of variance to test for significance of treatment differences as described by Snedecor and Cochran(1982).The treatment means was partitioned using Duncan Multiple Range Test (Duncan, 1955).

Results and Discussion

Land equivalent ratio.

The effect of crop cultivar and crop row arrangement on land equivalent ratio between 2008 and 2010 cropping seasons is presented in Table 2. SAMSORG -14 had higher (1.19) combined land equivalent ratio relative to SAMSORG -17 (1.12). The effect of intercropped soyabean cultivars showed that TGx 1448-2E (1.14) had similar land use efficiency relative to SAMSOY 2 (1.16).
The 1SG:1SY crop row arrangement produced the highest combined total land equivalent ratio (LER) value which resulted in 27 percent yield advantage over the sole crop and relative to the remaining row arrangements. Among the treatment combinations, SAMSORG -17 intercropped with TGx 1448-2E in 1:1 row arrangement had the highest (1.41) land equivalent ratio followed by SAMSORG -14 intercropped with SAMSOY 2 in 2:1 row arrangement (1.34) whereas SAMSORG -17 intercropped with TGx 1448-2E in 1:2 row arrangement gave the least LER of 0.98. This beneficial effects of intercropping may be attributed to less competition for growth resources and the eventual productivity by both crops. Similar views have been reported by Tajudeen (2010) who observed higher LER (1.16) in sorghum/cowpea intercrop which indicated a higher bio-economic efficiency. He recommended 1:1 and 2:1 crop row arrangement for grain and stover yield stability in sorghum in the semi-arid savanna ecological zone of Nigeria. Similarly, Clement *et al.* (1992) reported higher efficient land – use efficiency (1.47 and 1.77) of maize/soyabean intercrop in 1:2 spatial arrangement.

Stability of yield

The effect of crop cultivar and crop row arrangement during 2008 - 2010 cropping seasons on stability of yield in a sorghum/soyabean intercropping system is presented in table 3. SAMSORG -14 had more stable yield (3.34) relative to SAMSORG -17 (3.30). With respect to intercroppedSoyabean cultivars, TGx 1448-2E had higher yield stability (2.35) relative to SAMSOY 2 (3.29).

Over the three years, 1SG:1SY crop row arrangement resulted in the highest stability of yield (0.92) followed by 2SG:1SY (0.81), 1SG:2SY (0.80), and 2SG:2SY (0.78) crop row arrangements in that order. Among the treatment combinations, SAMSORG -17 intercropped with TGx 1448-2E in 1SG:1SY row arrangement exhibited the most stable yield relative to other row arrangements. The significant stability of yield observed in 1SG:1SY row arrangement indicates that consistent yield of component crops could be achieved in this crop row arrangement.This result corroborates the findings of Odion (1991) and Odion *et al.* (2008) who reported that alternate row arrangement in sorghum millet/groundnut or rice were generally more stable relative to the alternate stand arrangement.

Conclusion

The results of the present study have demonstrated the benefits of intercropping in the northern Guinea savanna of Nigeria. However, to achieve higher and sustainable productivity of sorghum/soyabean intercrop over a period of time, SAMSORG-17 intercropped with TGx 1448-2E in 1SG:1SY row arrangement be adopted for the northern Guinea Savanna.

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Table 1: The effect of crop cultivar and crop row arrangement on grain yield during 2008-2010 rain-fed seasonsin a Sorghum/Soyabean intercropping system at Samaru, Nigeria.

Treatment Mixture	2008 Sorghum(a) $Kgha^{-1}$ Grain yield	2008 Soyabean (b) $Kgha^{-1}$ Grain yield	2009 Sorghum(a) $Kgha^{-1}$ Grain yield	2009 Soyabean (b) $Kgha^{-1}$ Grain yield	2010 Sorghum(a) $Kgha^{-1}$ Grain yield	2010 Soyabean (b) $Kgha^{-1}$ Grain yield
SAMSORY - 14 with SAMSOY 2						
Sole	2250.05	1994.27	1413.44	1612.34	690.37	1745.06
1:1	1450.32	1644.429	893.90	636.11	582.72	729.75
1:2	1123.89	996.9	698.76	948.03	603.09	1159.38
2:1	1877.86	764.04	1438.99	587.59	789.13	495.31
2:2	1311.14	706.44	504.56	910.55	444.08	944.63
SAMSORG-14 with TGx1448-2E	2250.5	1643.24	1413.44	1835.55	690.37	2210.49
Sole						
1:1	1714.87	994.43	991.05	798.27	549.13	767.78
1:2	1186.81	1253.73	565.33	1250.98	412.34	1203.45
2:1	1902.45	507.19	1191.38	389.44	879.75	408.89
2:2	1046.81	683.97	646.42	1354.17	433.7	877.96
SAMSORG - 17 with SAMSOY 2	2071.01	1994.27	980.93	1612.34	1124.32	1743.06
Sole						
1:1	1567.87	1654.11	374.25	763.09	826.30	811.48
1:2	724.58	1208.73	608.88	1050.55	373.95	1137.53
2:1	1929.5	751.00	504.35	641.85	703.46	478.14
2:2	1329.71	1163.14	306.19	1358.61	581.66	858.15
SAMSORG - 17 with TGx1448-2E	2071.01	1643.24	980.93	1835.55	1124.32	2210.09
Sole						
1:1	1928.74	1294.76	801.08	1134.81	781.36	815.31
1:2	592.74	1105.46	287.97	1599.75	377.53	1067.90
2:1	1794.49	546.63	728.01	744.93	774.44	554.07
2:2	1709.43	743.4	636.25	1010.55	597.59	701.66

Table 2: The effect of crop cultivar and crop row arrangement on land equivalent ratio during 2008 – 2010 rain-fed seasons in a sorghum/soyabean Intercropping system at Samaru, Nigeria.

TREATMENT	2008			2009			2010			
Mixture	LER a	LER b	TLER	LER a	LER b	TLER	LER a	LER b	TLER	Mean
SAMSORG14withSAMSOY 2										
1:1	0.64	0.82	1.46	0.63	0.39	1.02	0.84	0.42	1.26	1.25
1:2	0.50	0.50	1.00	0.49	0.59	1.08	0.87	0.66	1.53	1.20
2:1	0.83	0.38	1.21	1.02	0.36	1.38	1.14	0.28	1.42	1.34
2:2	0.58	0.35	0.93	0.36	0.56	0.92	0.64	0.54	1.18	1.01
SAMSORG -14 with TGx 1448-2E										
1:1	0.76	0.61	1.37	0.70	0.43	1.13	0.8	0.35	1.15	1.22
1:2	0.53	0.76	1.29	0.40	0.68	1.08	0.60	0.54	1.34	1.24
2:1	0.85	0.31	1.16	0.84	0.21	1.05	1.27	0.18	1.45	1.22
2:2	0.47	0.42	0.89	0.46	0.74	1.20	0.63	0.40	1.03	1.04
SAMSORG -17 with SAMSOY 2										
1:1	0.76	0.83	1.59	0.38	0.47	0.85	0.73	0.47	1.20	1.21
1:2	0.35	0.61	0.96	0.62	0.65	1.27	0.33	0.65	0.98	1.07
2:1	0.93	0.38	1.31	0.51	0.40	0.91	0.62	0.27	0.90	1.04
2:2	0.64	0.58	1.22	0.31	0.84	1.15	0.52	0.49	1.01	1.13
SAMSORG -17 with TGx 1448 – 2E										
1:1	0.93	0.79	1.72	0.82	0.62	1.44	0.69	0.37	1.06	1.41
1:2	0.29	0.67	0.96	0.29	0.87	1.16	0.34	0.48	0.82	0.98
2:1	0.87	0.33	1.2	0.74	0.41	1.15	0.69	0.25	0.94	1.10
2:2	0.83	0.45	1.28	0.65	0.55	1.20	0.53	0.32	0.85	1.11

Table 3: Stability ofsorghum and soyabean intercrop as influenced by cultivar and crop row arrangement at Samaru Nigeria, between 2008-2010 rain-fed seasons.

TREATMENT	Standardized LER (sorghum)				Standardized LER (soyabean)				
Mixture	2008	2009	2010	Stan.LER/n	2008	2009	2010	Stan.LER/n	Stability of Yield
SAMSORG14withSAMSOY 2									
1:1	0.64	0.40	0.26	0.43	0.74	0.29	0.33	0.45	0.89
1:2	0.50	0.31	0.27	0.36	0.45	0.43	0.54	0.47	0.83
2:1	0.83	0.64	0.35	0.61	0.35	0.27	0.22	0.28	0.89
2:2	0.58	0.22	0.20	0.33	0.32	0.41	0.43	0.39	0.72
SAMSORG-14	1.00	0.63	0.31	0.65					0.65
SAMSORG -14 with TGx 1448-2E									
1:1	0.76	0.44	0.24	0.48	0.45	0.36	0.35	0.39	0.87
1:2	0.53	0.25	0.18	0.32	0.57	0.57	0.54	0.56	0.88
2:1	0.85	0.53	0.39	0.59	0.40	0.18	0.18	0.25	0.84
2:2	0.47	0.29	0.19	0.32	0.31	0.61	0.40	0.44	0.75
TGx 1448-2E					0.74	0.83	1	0.86	0.86
SAMSORG -17 with SAMSOY 2									
1:1	0.70	0.17	0.37	0.41	0.75	0.35	0.37	0.49	0.90
1:2	0.32	0.27	0.17	0.25	0.55	0.48	0.51	0.51	0.77
2:1	0.86	0.22	0.31	0.46	0.34	0.29	0.22	0.28	0.75
2:2	0.59	0.14	0.26	0.33	0.53	0.61	0.39	0.51	0.84
SAMSOY 2					0.90	0.73	0.79	0.81	0.81
SAMSORG -17 with TGx 1448 – 2E									
1:1	0.86	0.36	0.35	0.52	0.59	0.51	0.37	0.49	1.01
1:2	0.26	0.13	0.17	0.19	0.50	0.72	0.48	0.57	0.76
2:1	0.80	0.32	0.34	0.49	0.25	0.34	0.25	0.28	0.77
2:2	0.76	0.28	0.27	0.44	0.34	0.40	0.32	0.37	0.81
SAMSORG-17	0.92	0.44	0.50	0.62					