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Evaluation of Growth and Yield of Sorghum Cultivars as Influenced by Intercropping of Soybean

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ABSTRACT: The fast-growing world population and reduction in the land for agricultural purposes have threatened the demand for food thus making intercropping an indispensable farming practice. Hence, the objective of this paper is to evaluate the growth and yield of sorghum cultivars as influenced by intercropping of soybean at a Tertiary Institution Research Farm Ogbomoso, and the National Centre for Agricultural Mechanization (NCAM), Idofian during the 2021 cropping season using appropriate standard techniques. Data obtained show that sole sorghum out-yielded the intercropped and decreased as the population of component soybean decreased. A significantly lower number of pods 18.93 and 32.48 and seeds 79.2 and 68.9 per plant respectively for LAUTECH and NCAM were recorded at the treatment where full populations of both crops were intercropped. Irrespective of cultivar and location the lowest grain yield of sorghum at the intercropped was obtained at the population ratio 100SH:100SO but the least grain yields of soybean were recorded at the 100SH:25SO population ratio. Regardless of the sorghum cultivar, the highest intercropping advantage as measured by Land Equivalent Ratio (LER) and Land Equivalent Coefficient (LEC) indices was observed at 100SH:100SO with Samsorg 47 cultivar. This population ratio and sorghum cultivar is recommended for adoption.

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Simultaneous growing of two or more crops as a traditional agriculture practice is a popular farming system among tropical small-scale farmers (Musa *et al.*, 2011). It gives many biological, ecological, and socioeconomic benefits compared with sole cropping (Iqbal *et al.*, 2019) and was recognized as one of the alternative agronomic practices for ensuring food security and enhancing yield stability (Raseduzzaman, 2016). The system according to several authors helps to secure food supply to feed the world population by providing for almost 15–20% additional yield based on the practice of growing more than two types of crops at the same time (Altieri and Nicholls, 2017; Lithourgidis *et al.*, 2011). Soybean (*Glycine max* L.Merill) a leguminous crop in the family Fabaceae has gained popularity as an excellent source of protein for man and his livestock. Intercropping soybeans with cereals is

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common among the resource-poor farmers in the study area to meet the financial as well as the nutritional needs of the household. The productivity however has been reported to be low at the intercrop due to severe competition from the associated cereals (Undie *et al*., 2012). Egbe (2010) reported that increasing the plant population of soybeans beyond 333,000 plants /ha reduced sorghum yield. In another study, Josiah (2015) observed that the productivity in soybean/ sorghum was enhanced by row arrangement. In a recent study (Aydemir, 2018) considerable intercropping advantage with the land equivalent ratio (LER) above unity was reported in soybean/sorghum intercropping. Sorghum is an important cereal crop in many parts of the world, particularly the arid and semiarid regions. As xerophytes with a range of adaptations, it is readily available as feeding for almost all classes of livestock (Akhtar *et al*. 2013). In the southern Guinea savannah agroecology of Nigeria, sorghum is commonly grown with legumes to take advantage of drought but with no consideration of the population density and the appropriate sorghum cultivar with optimum productivity. Yield reduction under intercropping is associated with competition by component crops for nutrients, light, and moisture (Kermah *et al.* 2018). Hence, a proper understanding of compatible crops and the appropriate plant population are important factors for consideration for achieving optimum productivity. Peoples *et al*. (2009) and Kermah *et al.* (2001) had earlier noted when companion crops are compatible with interspecific facilitation and niche complementarity. In a recent study, Talent *et al.* (2020) noted that variety selection is an important consideration for improving productivity in cereal-legume mixture. Akunda (2001) cited in Egbe (2010) noted that plant population can be used as a tool to manage crop growth, maximize biomass the time required for canopy closure and crop yield, and should be considered important to maintain high potential yield and reduce competition between intercrops. Plant density was reported to affect leaf area index (LAI), with the consequent reduction in light interception, poor production of assimilates, decreased radiation use efficiency, competition, and overcrowding (Gan *et aI.*, 2002; Seran and Binta, 2010)). According to Caliskan *et al.* (2007) within certain limits, increased plant population decreased growth but the reverse occurred for yield per unit area. Rahman and Hossain. (2011) reported that increased plant density in soybean decreased yield components such as the number of pods per plant, seed per pod, 100 seed weight as well as seed yield.

Although studies have been carried out in sorghum/soybean mixture these earlier studies did not take into consideration the varietal differences among sorghum cultivars at various population densities for achieving optimum productivity at the intercrop. Hence, the objective of this paper is to evaluate the growth and yield of sorghum cultivars as influenced by intercropping with soybean

MATERIAL AND METHODS

Site description: The experimental site was established at Ladoke University of Technology (LAUTECH) and (National Center for Agricultural Mechanization (NCAM). Ladoke University of Technology Teaching and Research Farm Ogbomoso, Oyo State is located on latitude 8.16676°N and longitude 4.26804°E. The National Centre for Agricultural Mechanization (NCAM), is located at latitude 8.47988^0 N, and longitude 4.54181^0 E.

Planting materials: The planting materials used for the study were three sorghum cultivars (Samsorg 47, Samsorg 48, and Samsorg 49) and one soybean (TGX 1448-2E) that are widely cultivated in Nigeria. The planting materials were obtained from Oyo State Agriculture Development Programme (OYSADEP) station at Ogbomoso, Nigeria.

Treatments and Experimental Design: The treatments consist of a full population density of three sorghum cultivars intercropped with 100 %, 75 %, 50 %, and 25 % full population of soybean in a one-by-one alternate row arrangement. Sole crops of both soybean and sorghum were also included in the treatment as a check.

The experiment was laid out as a 4 x 3 factorial combination in a randomized complete block design (RCBD) in a split plot and replicated three times. The population density constituted the main plots while sorghum cultivars were assigned to the subplot treatments.

Cultural Practices: The land was plowed and harrowed and the field was marked out into blocks. Each plot was 3.0 m by 3.0 m with 1.0 m between blocks and 0.5 m between plots. Pendimenthalin (500 EC) {N-(1- ethylpropyl)-3, 4 dimethyl-2, 6 dinitrobenzene amine} mixed with glyphosate (N-phosphonomethyl-glycine) at the rate of 1.5 liter/ha each was applied immediately after planting using knapsack sprayer. This was followed with manual weeding when due such that the experimental field was weed-free during the trial. Lambdacal {(R-cyano- (3-phenoxyphenyl) methyl} (1S, 3S)-3-{(Z)-2-chloro-3, 3, 3-trifluoropropane -1- carboxylate) a systemic insecticide was applied to the sorghum during the milk dough stage to prevent insect pest at the rate of 40ml/20litres of water as recommended by the manufacturer. N.P.K 20:10:10 was applied to sorghum at 3 weeks after planting at the rate of 60 kgN/ha and was supplemented with urea at the rate of 20 kgN/ha at 8 weeks after planting. Single superphosphate at the rate of 40 kg P_2O_5 was applied to soybeans two weeks after planting. Soybean was harvested manually from the five tagged plants by uprooting the entire plants. This was done at the physiological maturity before shattering when the leaves turned yellow and started dropping from the plant. The harvested plants were further dried before threshing and winnowing. Sorghum was also harvested manually using a knife to cut the panicles from the five tagged plants at the inner rows. The harvested panicles were sundried before threshing.

Data Collection and Analysis: The following parameters were measured from the five tagged plants:
Soybean: Plant height and stem girth at 8 WAP, number of branches, pods, seeds/plant, and grain yield/hectare. Sorghum: Plant height at 8 WAP, head length, weight of 100 seeds, and grain yield/hectare.

Evaluating Intercropping Efficiency: The efficiency of intercropping was determined using the Land Equivalent Ratio (LER) and Land Equivalent Coefficient (LEC) indices.

Land Equivalent Ratio (LER). The LER was calculated in equation 1as described by (Willey, 1985) and used by Afe (2020).

$$LER = \frac{Y_{aa} + Y_{ab}}{Y_{bb}} \quad (1)$$

Where: Yab= Yield of soybean at the intercrop; Yaa=Yield of soybean at the sole; Yba=Yield of sorghum at intercrop; Ybb= Yield of sorghum at the sole

Land Equivalent Coefficient (LEC). This is an index for measuring the interaction and productivity potential in an intercrop. It was calculated as in equation 2 as described by Adetiloye and Ezedima (1983) cited by Afe (2020).

$$LEC = Ls \times Lo \quad (2)$$

Where: Ls and Lo are the partial or relative yield ratio of the intercrop yield to the sole crop yield for sorghum and soybean respectively.

All collected data were subjected to analysis of variance (ANOVA) using DSAASTAT 2011 version and the treatment means where significant differences existed were separated using Duncan's Multiple Range Test at a 5% level of probability.

RESULTS AND DISCUSSION

The meteorological data and physicochemical properties of the soil at the two locations during the trial are presented in Tables 1 and 2. The highest rainfall 39.70 cm and 18.2.00 cm respectively for NCAM and LAUTECH during the experiment was in September. The mean rainfall was 25.57 cm and 13.72 cm, with the mean temperature, ranging between 49.10 – 54.90 and 51 – 57^{0}C for LAUTECH and NCAM respectively with the highest relative humidity of 88% in August at NCAM and 85% in August and September at LAUTECH. The textural class of soil at the two experimental sites is sandy loam. The NPK was generally low with neutral pH at both locations. The organic carbon and total N at LAUTECH were higher than NCAM but the available P and exchangeable Mg at the NCAM location were higher than LAUTECH.The nutrient status of the two locations differs and was generally low with the critical value (USDA-SCS, 1974; Enwezor *et al.*, 1989). The differences in soil fertility between the two locations could be attributed to soil management and crop history at the two locations. For instance, the LAUTECH location has been under-utilized whereas, cultivation at the NCAM location commenced about two years. According to Chen *et al.* (2018), continuous cropping on the same piece of land was identified as a major factor responsible for nutrient loss and soil degradation since the nutrient uptakes during plant growth were not returned to the soil after harvest

Table 1: Meteorological data of the experimental site

Months	Rainfall (cm)		Mean temperature (O^0C)		Relative humidity (%)	
	[1]LAUTECH	[2]NCAM	LAUTECH	NCAM	LAUTECH	NCAM
June	15.4	35.00	52.0	57	83.0	81.0
July	17.5	23.0	49.9	53.0	84.0	77.0
August	18.0	23.75	49.1	57.0	85.0	88.0
September	18.2	39.70	50.4	53.0	85.0	84.0
October	10.5	14.10	52.1	55.0	83.0	85.0
November	13.0	17.90	54.8	57.0	71.0	77.0
December	14.0	---	54.9	51.0	50.0	59.0
Total	82.3	153.45	333.4	383.0	541.0	551.0
Mean	13.22	25.57	55.56	54.7	77.28	78.71

Source: 1 Oyo State Agricultural Development Project, Planning, Monitoring and Evaluation Department , 2. Lower Niger River Basin Development Authority (Hydrology section)

Table 2: Pre-Planting Physical and Chemical Properties of the Experimental Site

	Location	
	LAUTECH	NCAM
Sand	85.28	79.0
Silt	12.60	13.0
Clay	12.12	8.0
Textural class	Sandy loam	Sandy loam
Organic Carbon (%)	1.99	1.21
Total Nitrogen (%)	0.22	0.14
AvailablePhosphorus; (mg/kg)	5.97	6.68
pH	6.12	6.9
Exchangeable Mg (Cmol/kg)	1.56	1.38
Exchangeable K (mg/kg)	0.13	0.24
Exchangeable Ca (mg/kg)	5.66	1.98
Exchangeable Na (Cmol/kg)	0.27	0.70
Exchangeableacidity, (Cmol/kg)	0.32	0.30
Mn (mg/kg)	57.39	110.0
Fe (mg/kg)	420.05	98.0
Cu (mg/kg)	4.03	1.04
Zn (mg/kg)	6.87	0.92

The inherent low nutrient status of savannah soils as observed at the two locations has been reported by Labaran and Idris (2016) due to continuous farming and indiscriminate application of synthetic fertilizers which is a common practice among the farmers in the zone. Similarly, Tivet *et al*. (2013) opined that changes in the soil properties due to continuous cultivation was a major factor responsible for soil degradation and a decline in crop yield. The significant effect of population density and sorghum cultivars on plant height, the number of branches, pods as well as the number of seeds per plant of soybean is presented in Table 3. Regardless of location, the number of branches, pods, and seeds per plant was higher at the sole compared to the intercropped population ratios.

Table 3: Main effect of population density and sorghum cultivars on the plant height at 8 WAP, number of branches and pods per plant, and number of seeds per pod of soybean

Population Ratios	Plant height at 8WAP (cm)		Number of branches/plant		Number of pods/plant		Number of seeds/plant	
SH : SO	Lautech	NCAM	Lautech	NCAM	Lautech	NCAM	Lautech	NCAM
100 : 100	32.33a	37.00a	1.17d	2.80d	18.93e	32.48e	79.2e	68.97e
100 : 75	30.43b	34.10b	1.87cd	3.65c	22.73d	36.77d	86.9d	73.57d
100 : 50	29.77bc	33.23b	2.37bc	4.11bc	25.50c	40.00c	100.8c	81.17c
100 : 25	28.97c	33.93b	2.83ab	4.40b	27.67b	41.76b	112.3b	89.76b
Sole	28.10c	32.23c	3.27a	5.51a	30.40a	50.72a	126.8a	114.70a
SEM	0.44	0.63	0.29	0.23	0.69	0.30	0.19	0.27
Cultivars								
Samsorg-47	30.82a	34.16a	2.64a	4.21a	26.68a	40.81a	10.98a	95.55a
Samsorg-48	30.72a	32.16b	2.20a	4.17a	26.22a	40.33a	10.37b	84.46b
Samsorg-49	30.70a	33.50ab	2.06a	3.90a	25.24a	39.89a	9.02c	79.88c
SEM	NS	0.63	NS	NS	0.69	NS	0.19	0.27
PD X CU	NS	*	NS	*	*		*	

Values with same letter (s) under the same treatment and column are not significantly different at 5 % level of probability by Duncan's Multiple Range Test. SH= Sorghum, SO= soybean, NS= Non WAP= Weeks after planting, significant, *= Significant.

Table 4: Plant height at 8 WAP, weight of 100 grains and head length of sorghum

Population Ratios	Plant height (cm) 8 WAP		Head length (cm)		Weight of 100 grains (g)	
SH : SO	Lautech	NCAM	Lautech	NCAM	Lautech	NCAM
100 : 100	35.43a	46.98a	44.87a	39.01a	2.73a	2.84
100 : 75	31.90b	44.88ab	42.80a	38.88a	2.73a	2.45a
100 : 50	31.40b	41.96bc	44.40a	41.63a	2.80a	2.54a
100 : 25	31.60b	41.92bc	46.53a	39.02a	2.87a	2.48a
Sole	33.27b	39.88c	45.90a	42.97a	2.97a	2.73a
SEM	0.68	0.96	NS	NS	NS	NS
Cultivars						
Samsorg-47	31.20ab	43.24a	46.05a	39.00a	2.84a	2.62a
Samsorg-48	33.19ab	44.23a	47.70a	42.88a	2.98a	2.66a
Samsorg-49	33.96a	44.36a	44.16a	38.78a	2.65a	2.54a
SEM	0.68	0.96	NS	NS	NS	NS
PD X CU		*	NS	NS	NS	NS

*Values with same letter (s) under the same treatment and column are not significantly different at 5 % level of probability by Duncan's Multiple Range Test. SH= Sorghum, SO= soybean, NS= Non WAP= Weeks after planting, significant, *= Significant.*

The number increased as the population of soybean decreased at the intercropped. The number of pods and seeds per plant at the treatment where the full population of both crops was intercropped (100SH:100SO) was significantly lower compared to other intercropped population ratios. Although the population ratios 100SH:75SO and 100SH:100SH:50SO had a similar number of branches per plant, the number of pods and seeds produced per plant at the population ratio 100SH:50SO were significantly higher than 100SH:75SO at the two locations. A reduction in the population of soybean to 25 % at the intercropped (100SH:25SO) significantly produced more pods and seeds per plant than the other intercropped population ratios. There was no significant difference in the number of branches and pods produced per plant in the soybean as influenced by sorghum cultivars but the number of seeds per plant was significantly influenced. The soybean intercropped with the samsorg 47 cultivar was superior in the number of seeds to those intercropped with other cultivars. Significantly poor seeds were recorded with the soybean intercropped with the samsorg 49 sorghum cultivar compared to the other two cultivars. Generally, the height of sorghum at the NCAM location was slightly taller than at the LAUTECH location (Table 4). At 8 WAP, the plant height at the treatment where a full population of both crops was mixed (100SH:100SO) significantly produced taller plants than other intercropped population ratios. The height of sorghum at the sole was at par with the intercropped population ratios 100SH:50SO and 100SH:25SO. The difference in the plant height between the population ratios 100SH:100SO and 100SH:50 SO was also not significant at the two locations. There was no significant difference in plant height, head length, and seed weight among the sorghum cultivars. Although Samsorg 49 cultivar was taller than the other cultivars, it was not statistically manifested. The weight of 100 seeds and the head length of sorghum were not significantly influenced by the population density of component soybean. The plant height of both crops increased with increased plant population with a population ratio of 100SH:100SO where the full population of both crops was intercropped significantly taller than the sole. A similar response of plant height to population density was reported by several authors (Rahman *et al.*2004; Alani *et al.* 2018). This increased plant height at a high population ratio according to Renderson and Lauer (2003) was due to stem elongation with an attendance number of nodes/plant (Oh *et al.*, 2007), competitive shading within the leaf canopy architecture (Hiyane *et al.*, 2010) with the consequent reduction in the photosynthetic and net assimilation of individual plants (Rahman and Hossain, 2011 cited in (Domimqueue and Hrime 1978). To achieve optimum yield in an intercrop, Kermah *et al.* (2018) observed that a proper understanding of the appropriate plant population per unit area is one of the main agronomic practices that is required. Similarly, Okworr *et al*. (1991) and Lucas (1992) cited in Ajayi *et a*l. (2019) opined that plant height is the most important feature that determines the competitive ability of light. The interaction between population density and sorghum cultivars on the grain yield of soybean is presented in Figure 1.

Irrespective of location, the grain yield of soybean decreased as the population decreased at the intercropped. Regardless of the sorghum cultivar, the highest grain yield at the intercropped was obtained at the treatment where the full population of soybean was intercropped with the full population of sorghum (100SH:100SO). Intercropping soybean with samsorg 9 at the full population of both crops significantly had more grain yield compared to intercropping with samsorg 7 and samsorg 8 cultivars. Irrespective of the sorghum cultivar, similar grain yield was recorded at the population ratio 100SH:25SO. The interaction between population density and sorghum cultivars on the grain yield of sorghum is presented in Figure 2.

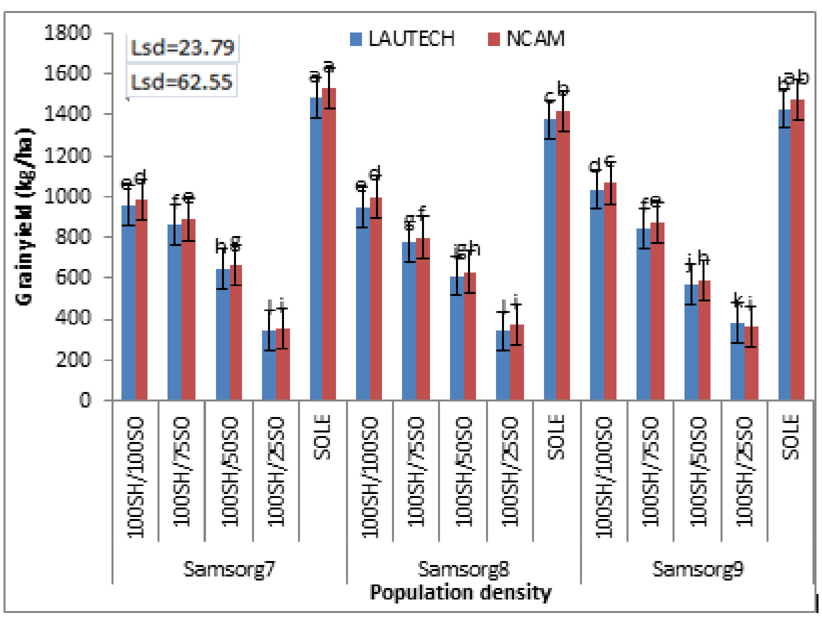

Fig 1: Interaction between population density and sorghum cultivars on grain yield of soybean

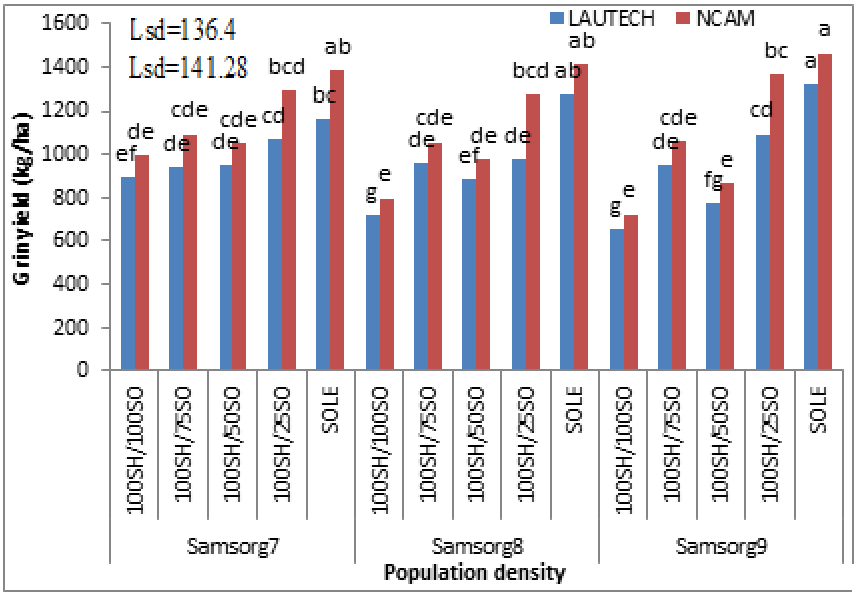

Fig 2: Interaction between population density and sorghum cultivars on the grain yield of sorghum at LAUTECH and NCAM locations

Regardless of sorghum cultivars and location, the sole significantly out yielded the intercropped population ratios. The grain yield decreased as the population of component soybean decreased at the intercropped. The least grain yield for all the cultivars at the two locations was obtained at the treatment where a full population of both crops (100SH:100SO) was intercropped. There was no significant difference in the grain yield between the sole and the intercropped population ratio 100SH:25SO intercropped with samsorg 7 and samsorg 8 cultivars at the NCAM location. Except for intercropping involving Samsorg 9 cultivar at the component population 100SH:50SO all the treatments demonstrated intercropping advantage as measured by LER and LEC indices. The highest LER 1.41 and LEC values respectively for Lautech and NCAM were obtained at the treatments where a full population of both crops was intercropped (Table 5).

Table 5: Intercropping efficiency in sorghum cultivars intercropping with soybean at different population ratios at LAUTECH and NCAM

	Grain yield (Kg/ha)		Grain yield (Kg/ha)									
	LAUTECH		NCAM		LAUTECH		NCAM		LER		LEC	
Ratios SH :SO	Sorghum grain yield (kg/ha)	Soybean	Sorghum	Soybean	SH	SO	SH	SO	LAUTECH	NCAM	LAUTECH	NCAM
100/100	895.55	954.91	994.1	983.56	0.77	0.64	0.71	0.64	1.41	1.35	0.49	0.45
100/75	939.99	860.63	1092.21	886.45	0.81	0.58	0.79	0.58	1.38	1.37	0.46	0.46
100/50	948.88	648	1053.32	667.44	0.81	0.44	0.76	0.44	1.25	1.19	0.35	0.33
100/25	1066.66	341.98	1289.98	352.24	0.92	0.23	0.93	0.23	1.15	1.16	0.21	0.21
SOLE	1162.22	1484.95	1384.98	1529.5		-			1	1	0.25	0.25
	SAMSORG 8											
100/100	717.78	945	796.74	997.61	0.56	0.68	0.56	0.7	1.24	1.26	0.38	0.39
100/75	955.55	776.25	1056.65	799.54	0.56	0.7	0.75	0.56	1.26	1.31	0.39	0.42
100/50	882.21	612.01	978.88	630.37	0.69	0.44	0.69	0.44	1.13	1.31	0.3	0.42
100/25	974.63	340.69	1275.53	362	0.76	0.25	0.9	0.26	1	1.15	0.19	0.23
SOLE	1273.33	1377	1413.32	1418.31	--	----	---	---	1	1	0.25	0.25
	SAMSORG 9											
100/100	651.11	1034.99	722.73	1066.04	0.59	0.73	0.49	0.72	1.31	1.21	0.43	0.35
100/75	948.88	843.75	1061.1	869.07	0.72	0.59	0.73	0.59	1.31	1.32	0.42	0.43
100/50	777.77	571.84	863.32	588.66	0.59	0.4	0.59	0.4	0.98	0.99	0.24	0.24
100/25	1092.01	395.96	1367.84	383.15	0.83	0.28	0.93	0.26	1.11	1.18	0.23	0.24
SOLE	1317.78	1430.95	1462.21	1473.87	-	----	----	----	1	1	0.25	0.25

Regardless of location, the sole out yielded the intercropped for the crops with the NCAM location slightly yielded than the Lautech location possibly due to higher precipitation at NCAM during the trial. The reduction in the yield was more pronounced with soybean. This superiority of the sole over the intercropped could be due to overcrowding, particularly at high population density, and the absence of competition for growth resources (light, water, and nutrient) at the sole that was present at the intercrop. A similar observation was reported by Ajeigbe *et al.* (2019). The reduction of soybean at the intercropped was due to a severe reduction in the yield and yield components viz; the number of branches and pods per plant. The reduction in the yield and yield components of soybean at high population density as observed in this study is consistent with the findings of other researchers (Elijah, 2001; Afe *et a*l., 2020; Silva *et al.,* 2021) which were attributed to the ability of the plant to change its morphology and yield components to adapt to imposed population density.

Irrespective of sorghum cultivars, reasonable intercropping advantage was observed at population ratios 100SH: 100SO and 100SH:75SO due to the increased partial land equivalent ratio of soybean. The relatively poor intercropping advantage at the lower population ratios of 100SH:50SO and 100SH:25SO was attributed to the low yield of soybean that was not compensated for by the increased sorghum as observed in the lower partial LER for soybean at these population ratios.

Conclusion: The growth and yield of sorghum cultivars and soybean were influenced by intercropping. The grain yield of sorghum increased as the population of component soybean while the seed yield of soybean decreased with the decreasing population at the intercrop. Intercropping advantage as measured by LER and LEC indices demonstrated reasonable intercropping advantage at population ratios 100SH:100SO and 100:75SO with the highest with Samsorg 7 cultivar. Therefore for efficient utilization of natural resources in sorghum/soybean intercropping these population ratios and Samsorg 47 are recommended for adoption.

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