



RESEARCH ARTICLE

ASSESSMENT OF SORGHUM/OKRA INTERCROP PRODUCTIVITY, COMPETITIVE BEHAVIOR AND PROFITABILITY IN SOUTHERN GUINEA SAVANNAH AGROECOLOGY, NIGERIA

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ABSTRACT

Sorghum-okra intercropped at different population ratios and introduction periods were studied during the 2021 cropping season. Four population densities of okra (100 %, 75 %, 50 %, and 25 %) were introduced to sorghum three times [same time (ST), two weeks before planting (2WBP) and two weeks after planting (2WAP)] in a factorial combination in a randomized complete block in split plot, replicated three times. Sole sorghum and okra were included in the treatments as a check. Regardless of population ratios, the yield of sorghum increased as the population density of okra decreased and with further delayed at the time of introduction. Land equivalent ratio (LER) demonstrated intercropping advantage at all population ratios and time of introduction. The area time equivalent ratio (ATER) index, however, indicated no meaningful intercropping advantage. Competitive ratio (CR) showed that okra was more competitive than sorghum when full populations of both crops were intercropped at all times of introduction. Interestingly, however, reduction in the population of okra to 75 % and below, sorghum was more competitive than okra. The Aggressivity (A) values were positive for okra and negative for sorghum when it was planted two weeks ahead of sorghum (2WBP). Monetary advantage (MA) was positive in all the treatments. The discrepancy and inconsistency among the indices for assessing intercropping efficiency suggest that using one index may be misleading and hence, an appropriate index should be used based on the objective of the grower.

KEYWORDS

Aggressivity, competitive ratio, land equivalent ratio, monetary advantage, system productivity index.

1. INTRODUCTION

Intra and inter-competition in crop mixture are considered a major factor responsible for yield reduction compared to sole crop in intercropping (Oseni, 2010; Dantata, 2017; Afe, 2020). This yield reduction can, however, be minimized if agronomic practices such as relative time of planting component crops and population density are manipulated. The relative time of introduction of component crops is an important agronomic practice that can enhance productivity in crop mixtures. Some researcher reported that planting at different times in an intercrop will improve productivity and minimize competition of growth-limiting factors since component crops had full utilization of growth factors because they occupy the land throughout the growing season (Andrew, 1972; Willey, 1979 (cited in Addo-Quaye, 2011). In another study, they attributed yield reduction in an intercrop to below and above-ground interaction which according to the study is likely to vary depending upon the temporal and spatial differences in the resource use components (Aggrawal et al., 1992 (cited in Oseni, 2010). The complementary effect for efficient utilization of natural resources that could translate to yield advantage seemed to occur when component crops have different growing periods such that the demands for natural resources occur at different times. Some researchers opined that the yield reduction in medium-maturing cowpea intercropped with maize was largely due to the demand for natural resources of cowpea during flowering and podding that coincided with tasselling and silking in maize (Afe and Olofintoye, 2013).

Higher competition and dominance of sorghum over cowpea in sorghum/cowpea intercrop was reported (Aliyu, 2010; Afe, 2020). The

profitability of the intercrop over their respective sole was also reported in the same study. Proper understanding of resource use as influenced by population density and time of introduction of component crops such that the demand for natural resources among the component crop will occur at different times will not only enhance productivity but will also provide a scientific basis for recommending appropriate crop combinations at the intercrop. Several indices such as land equivalent ratio (LER), land equivalent coefficient (LEC), area time equivalent ratio (ATER), aggressivity (A), relative crowding coefficient (RCC), system productivity index (SPI), monetary advantage (MA) among others have been used to interpret intercropping advantages and competition among component crops in crop mixture (Ghosh, 2004; Oseni, 2010; Ijoyah, 2016; Afe et al., 2017; Awoniyi et al., 2020). The present study was designed to assess the productivity and competitive behavior in sorghum/okra intercropping as influenced by population ratio and time of introduction with a view of providing information on the appropriate index for assessing intercropping efficiency in crop mixture.

2. MATERIAL AND METHODS

2.1 Description of experimental site, experimental design, and crop management

The experiment was conducted during the 2021 cropping season, at the Teaching and Research Farm, Faculty of Agriculture, Kwara State University, Malete (latitude 14°06' N, longitude 35°33' E) and National Center for Agricultural Mechanization (NCAM) Farm Idofian (Latitude 14° 03' N, longitude 35°22' E). Sorghum (Samsong 49) and okra (Clemson)

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cultivars respectively, were obtained from Oyo State Agriculture Development Program (OYADP), and premier seeds, Ilorin were used for the trial. Six population densities of sorghum and okra (100S:100 OK, 100S:75 OK, 100S:50 OK, 100S:25OK, 100 S: 00 OK, 00S: 100OK where S and OK represented sorghum and okra respectively) and three times of introductions [same time (ST), two weeks before planting (2WBP), two weeks after planting (2WAP)] were laid out as 3 x 6 factorial combination in a randomized complete block design (RCBD) in split lot and replicated three times. The time of introduction constituted the main plot, while population densities were assigned to the sub-plot treatments.

Pendimethalin (500 EC) [N-(1- ethyl propyl)-3, 4 dimethyl-2, 6 dinitrobenzene amine] a pre-emergence herbicide was applied as specified by the manufacturer immediately after the first planting using knapsack sprayer. This was followed with manual weeding when due such that the experimental field was weed-free during the trial. Lambda cylothrins [(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 and okra to prevent insect pest. N.P.K (20:10:10) was applied to sorghum at 3 and 6 weeks after planting at the rate of 60kgN/ha and N.P.K 20:10:10 was applied to okra at the rate of 80kgN/ha at 3 weeks after planting. Sorghum and okra were harvested manually from five tagged plants in the inner rows.

2.2 Intercropping efficiency, competitive behavior, and economic advantage.

The efficiency of intercropping, competitive behavior, and monetary advantage of the mixture were determined using the following indices:

Land equivalent ratio (LER) which assessed the biological efficiency of intercropping in the utilization of natural resources compared to sole cropping was calculated as proposed by (Willey, 1985).

$$LER = (Yab/Yaa) + (Yba/Ybb),$$

Where: Yaa and Ybb are the sole yields of crops a and b, and Yab and Ybb are the intercrop yields of crops a and b, respectively. LER values greater than unity were considered advantageous.

Competitive ratio (CR). The CR describes the degree of competition among component crops in the mixture by measuring the ratios of individual LERs of the two-component crops along with the proportion in which they were sown in the mixture. It was calculated using the formula proposed (Willey and Rao, 1980). A higher CR value indicates a higher competitive ability.

$$CR (\text{sorghum}) = Ls \times Zso/Lm \times Zos,$$

$$CR (\text{okra}) = Lo \times Zos/Ls \times Zso,$$

Where: Ls and Lo are the partial LER for sorghum and okra, respectively; Zso and Zos = proportions of sorghum and okra, respectively.

Aggressivity (A), is a measure of how much a relative yield increase of one species (dominant) is greater than of the other species (dominated or recessive) in the mixture. The value of A was calculated by the formula proposed (McGilchrist, 1965). The A value for component crops a and b is usually the same, but the dominant crop gives a positive value, while the dominant crop gives a negative value. When the value of A is high it indicates a higher difference between the actual and expected yield.

$$Aab = \frac{Yab - Yba}{Yaa \times Zab - Ybb \times Zba}$$

Where:

Aab = Aggressivity value for component crop a,

Yab = Intercrop yield of crop a,

Yba = Intercrop yield of crop b,

Zab and Zba = Sown proportions of crops a and b in the intercrop

System productivity index (SPI) an index for standardizing the yield of the secondary crop (okra) in terms of the primary crop (sorghum). The index that is also used to observe the intercrop combination where growth resources are most effectively utilized and as well maintain stable yield was calculated as:

$SPI = (SA/LB \times Lb) + Sa$ (Odo, 1991). Where: SPI = System productivity index, SA and LB = Mean yield of sorghum and okra in the sole cropping, Sa and Lb = Intercrop yield of sorghum and okra.

MAI which shows the economic advantage of the intercropping system was calculated as described (Ghosh, 2004).

$$MAI = (\text{Monetary value of combined intercrops}) (LER - 1) / LER.$$

The economic values of sorghum and okra were estimated based on the prevailing market prices of the two crops at Ilorin during the trial. Respectively, N150. 00/kg and N80.00/kg were the prices of sorghum and okra.

2.3 Data Analysis

All the data collected were subjected to analysis of variance using DSAASTAT .1.101 version. (2011) statistical package and the treatments were separated using Duncan's New Multiple Range Test at a 5% level of probability.

3. RESULTS

The grain yield of sole sorghum when simultaneously planted and when okra was planted two weeks before sorghum was not significantly different from the intercrop population ratio 100S:25OK. The observation is however not the same with the treatments when sorghum was planted two weeks before okra as the sole was found to be significantly different from the component population ratio 100S:25OK. Regardless of the time of introduction and location, the lowest grain yields were obtained at the treatment where full populations of both crops were intercropped (100S:100 OK).

The highest grain yield of sorghum 3047.41 kg/ha and 1968.86 kg/ha respectively for Malete and NCAM at the intercrop were obtained at population ratio 100S:25OK and when sorghum was planted two weeks before okra (2WBP). Irrespective of the time of introduction and population density, fruit yield of okra was higher at the sole than the intercropped at both locations. The highest fruit yield was obtained at the full population 100S:100OK where okra was planted two weeks ahead of sorghum (2WAP).

The LER values at the NCAM location were found to be higher than the Malete location at the time of introduction. There was no meaningful intercropping advantage at the population ratio 100:50 and 100:25 at all periods of introduction of okra. Indeed, it was disadvantageous at the Malete location at a population ratio of 100S: 50 OK when sorghum was planted two weeks ahead of okra and population ratio 100S:25 OK when okra was planted two weeks before sorghum. There was no reasonable intercropping advantage as measured by the ATER index at all population ratios tested and the three periods of introduction except at the NCAM location at the population ratio 100S:100 OK when sorghum was planted two weeks ahead of okra (2WBP).

Regardless of the time of introduction and location, okra was found to be more competitive than sorghum when the full population of the two crops was intercropped (100S:100 OK). Interestingly, however, reduction in the population of okra to 75% and below, sorghum was found to be more competitive than okra. The competition was more pronounced at the population ratio when 25% of okra was intercropped with sorghum (100S:25 OK).

The aggressivity (A) did not follow a similar trend with the CR. Simultaneous planting of the two crops (ST) and two weeks before planting (2WBP), the A values were positive for okra and negative for sorghum at the two locations except at population ratio 100S:25 OK. These values decreased as the population of okra decreased. The A values were positive for okra and negative for sorghum at all population ratios, particularly at the Malete location when planted two weeks ahead of sorghum (2WAP). Although, SPI values were inconsistent the values at Malete were higher than NCAM location at all periods of introduction and population ratios.

Generally, all population ratios and time of introduction tested demonstrated economic advantage as observed in positive MAI values. The MAI values at the NCAM location were higher than the Malete locations and decreased with the reduction in the population of okra. The highest value N398, 200.08 was recorded at the NCAM location at the population ratio 100S:100 OK and 2WBP treatment.

4. DISCUSSION

The efficiency of intercropping as measured by the LER index differs among the population ratios, time of introduction, and locations. For instance, the LER index demonstrated intercropping advantage when the two crops were planted at the same time at the population ratio 100S:50 OK and beyond was only for the NCAM location. Except at 100S:100 OK population ratios, there was no meaningful intercropping advantage at the Malete location. The observed intercropping advantage using LER is consistent with the findings of other researchers: in sorghum/groundnut; in sorghum/cowpea intercropping due to complementarities of the two crops (Ghosh, 2004; Oseni, 2010; Afe, 2020).

At high population densities (100S:100 OK and 100S:75 OK) the decreased yield of sorghum was compensated for by increasing the yield of okra as observed in the partial LER. This increased yield of okra was higher at the NCAM location than at Malate and was responsible for a higher intercropping advantage at NCAM. The intercropping disadvantages at the population ratio 100S:25 OK were due to a significant reduction in the yield of okra due to a low population that could not be compensated for by the yield of sorghum. Thus, the combined LER was lower than unity. This observation is corroborated with the high grain yield and the value of the competitive ratio at this population ratio irrespective of the time of introduction and locations.

Interpreting intercropping advantage using ATER as observed in this study did not show any appreciable intercropping advantage as observed in the LER index. The reason for this discrepancy could be attributed to wide maturity dates between the two crops that were not taken into consideration by the LER index. Since the two crops have wide maturity dates such observation is expected. For instance, the duration of okra was 55 days while sorghum was 126 days, that is, about twice the number of days for okra. The implication of this is that using LER which is frequently used by researchers to interpret intercropping advantage may be misleading, hence the use of ATER for crops with wide maturity dates is appropriate.

Aggressivity which determines the competitive ability of component crops was positive for okra at the two locations at all population ratios except 100S: 25 OK showing that okra dominated sorghum. This result is supported by the findings but contradicted the report of who reported that sorghum dominated cowpea in sorghum/cowpea intercrop (Oseni, 2010; Afe, 2020). The conflict could be attributed to morphological/architectural differences between cowpea and okra. Although the two crops are understory concerning sorghum, okra is taller than cowpea. This height advantage of okra and its vigorous ability to grow taller at an early stage could have given okra an advantage to utilize natural resources better than sorghum because the maturity date is also shorter than sorghum. Some researchers opined that canopy height is one of the important features that determines the competitive ability of plants for light (Lucas, 1992; cited in Ajayi, 2020). Similarly, some researchers observed that the taller components in an intercrop intercept a major share of the light such that the growth rate of the two components will be proportional to the quantity

of photo-synthetically active radiation they intercepted (Palaniappan, 1985; cited in Ijolah and Usman, 2013). The CR measures the degree to which one crop competes with the other, the CR did not follow a similar trend with A as reported (Afe, 2020). In the present study, okra dominated sorghum but sorghum was found to be more competitive than okra except at the treatment where full populations of both crops were intercropped (100S:100 OK). This is explainable given the wide maturity dates between okra and sorghum. During and after the harvest of okra, senescence had set in with consequent reduction or absent demand for natural resources by okra. Hence, sorghum took over the entire growing cycle and since there was no competition from okra, it is expected that sorghum will be more competitive than okra. This competition is also expected to be more with the reduction in the population of okra and with further delay in the time of introduction as observed in this study. This observation is corroborated by high SPI values at the treatments where a full population of both crops was combined and is largely determined by okra as observed in the partial LER. This suggests that if okra is to be considered as a primary crop in sorghum/okra intercrop, maximum productivity will be obtained when it is sown two weeks ahead of sorghum.

However, all the treatments demonstrated economic advantage as observed with the positive MAI values. It varies with locations, population ratios, and time of introduction. This suggests that complementarity between the two crops in the utilization of natural resources was translated into economic benefit over their respective sole crops. This result is supported by the findings (Oseni and Aliyu, 2010; Dhima et al., 2007). The higher economic benefit at NCAM location over Malete as observed was due to increased yield of okra. Hence, any agronomic practice that will enhance okra yield will be of economic benefit in sorghum/okra intercropping. The highest MAI (N 398,200.08) was obtained at NCAM at the treatment where the full population of both crops was intercropped and where sorghum was planted two weeks before okra (2WBP).

Overall, discrepancies and inconsistencies were observed among the indices of interpreting intercropping advantage in the present study. The implication is that using one index to assess intercropping efficiency may be misleading and hence, for a meaningful intercropping advantage appropriate index should be used based on the objective of the grower.

Table 1: Grain, fruit yield land equivalent ratio and area time equivalent ratio in sorghum/ okra intercropping at Malete and NCAM

Population Ratio													Time of introduction			
Same time																
S : OK		Grain yield (kg/ha)		Fruit yield (kg/ha)		Partial LER				LER		ATER				
	MALETE	NCAM	MALETE	NCAM	MALETE		NCAM		MALETE	NCAM	MALETE	NCAM				
					S	OK	S	OK								
100:100	1228.20d	1213.87c	5044.43b	6803.32b	0.54	0.89	0.61	0.89	1.43	1.50	1.01	1.08				
100:75	1488.70c	1595.44b	3144.98c	4588.31c	0.45	0.55	0.80	0.60	1.00	1.40	0.78	1.12				
100:50	1699.92d	1633.08b	2186.08d	3264.34d	0.62	0.38	0.82	0.42	1.01	1.24	0.82	1.04				
100:25	2661.26a	1958.68a	1047.19e	1331.35e	0.98	0.38	0.98	0.17	1.16	1.15	1.07	1.07				
SOLE	2711.13a	1989.21a	5654.43a	7593.32a					1.00	1.00	1.00	1.00				
Two weeks before planting																
					Partial LER				LER		ATER					
					S	OK	S	OK								
100:100	1699.22d	1591.37c	3991.99b	4515.55b	0.46	0.77	0.73	0.97	1.23	1.70	0.87	1.24				
100:75	1880.33c	1608.37c	3075.76c	3289.98c	0.51	0.58	0.74	0.71	1.09	1.45	0.82	1.11				
100:50	1952.58c	1634.10c	2127.75d	1688.87d	0.53	0.41	0.75	0.36	0.94	1.11	0.74	1.08				
100:25	3047.41b	1968.86b	871.64e	936.91e	0.84	0.16	0.91	0.20	1.00	1.11	0.92	1.10				
SOLE	3626.37a	2154.04a	5169.99a	4612.21a					1.00	1.00	1.00	1.00				
Two weeks after planting																
					A				LER		ATER					
					S	OK	S	OK								
100:100	1414.32d	1778.26d	5545.55b	6973.32b	0.61	0.74	0.60	0.90	1.35	1.50	0.99	1.07				
100:75	1472.63cd	1372.66c	5016.64c	6103.30c	0.69	0.67	0.70	0.78	1.36	1.48	1.04	1.11				
100:50	1596.86bc	1675.82b	3314.96d	3222.19d	0.64	0.44	0.86	0.42	1.08	1.28	0.87	1.08				
100:25	1677.85a	1903.74a	1495.23e	1784.11e	0.73	0.20	0.98	0.23	0.93	1.21	0.84	1.10				
SOLE	2287.33a	1933.24a	7422.21a	7728.88a					1.00	1.00	1.00	1.00				

S=Sorghum, OK=Okra, LER=Land equivalent ratio, ATER= Area time equivalent ratio

Table 2: Competitive ratios, Aggressivisity, system productivity index, and monetary advantage index in sorghum/okra intercropping

Time of Introduction													
Same Time													
CR				A				SPI				MAI	
Population		Malete		NCAM		Malete		NCAM		Malete		NCAM	
SH	OK	SH	OK	SH	OK	SH	OK	SH	OK				
100	100	0.61	1.64	0.68	1.46	-0.35	0.35	-0.28	0.28	3646.85	2996.12	283,131.04	296,269.00
100	75	1.09	0.91	1.78	0.56	-0.29	0.29	0.00	0.00	2996.63	2797.43	0.00	277,795.75
100	50	3.26	0.30	3.90	0.26	-0.15	0.15	-0.02	0.02	2748.08	2488.23	9,052.83	180,149.75
100	25	21.8	0.05	23.10	0.04	0.24	-0.24	0.28	-0.28	3163.35	2307.45	182,693.57	132,356.29
Sole													
Two Weeks Before Planting													
CR				A				SPI				MAI	
Population		Malete		NCAM		Malete		NCAM		Malete		NCAM	
SH	SO	SH	OK	SH	OK	SH	OK	SH	OK				
100	100	0.59	1.69	0.75	1.32	-0.31	0.31	-0.24	0.24	4499.31	3700.26	186,106.49	398,200.08
100	75	1.17	0.85	1.39	0.71	-0.26	0.26	-0.35	0.35	4037.75	3145.78	85,951.45	285,582.63
100	50	2.59	0.39	4.16	0.24	-0.29	0.29	-0.08	0.08	3445.04	2422.85	65,935.35	85,261.61
100	25	21	0.05	18.20	0.00	0.17	-0.17	0.06	-0.06	3658.80	2406.42	0.00	97,831.99
Sole	00												
Two Weeks After Planting													
CR				A				SPI				MAI	
Population		Malete		NCAM		Malete		NCAM		Malete		NCAM	
SH	SO	SH	OK	SH	OK	SH	OK	SH	OK				
100	100	0.82	1.21	0.67	1.50	-0.13	0.31	-0.30	0.30	3123.31	2922.51	240,702.35	293,121.13
100	75	1.37	0.72	1.19	0.84	-0.21	0.21	-0.35	0.35	3018.63	2876.72	262,652.19	303,534.00
100	50	2.90	0.34	4.09	0.25	-0.21	0.21	-0.08	0.08	2618.44	2986.06	63,410.04	207,678.65
100	25	14.60	0.07	17.00	0.05	-0.07	0.07	0.06	-0.06	2138.64	2350.00	65,683.59	172,526.30
Sole	00												

CR=Competitive Ratio, A= Aggressivisity, SPI =System Productivity Index, MAI= Monetary Advantage Index, SH=Sorghum, Ok= Okra

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