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Growth and Yield of Sorghum as Influenced by Population Density and Time of Introduction of Component Okra

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ABSTRACT

A field trial was carried out at the Teaching and Research Farm of Kwara State University, Malete and National Center for Agricultural Mechanization (NCAM) during 2021 cropping season to investigate the productivity and intercropping advantage as influenced by population density and time of introduction in sorghum/okra intercropping. Four Population densities of okra (100 %, 75 %, 50 %, and 25 %) were intercropped with full population of sorghum at same time (ST), two weeks before planting (2WBP) and two weeks after planting (2WAP). Sole sorghum and okra were included in the treatments as a check. The treatments were arranged as 3x6 factorial combinations in a randomized complete block in split plot and replicated three times. Regardless of population ratios, the yield of sorghum increased as the population density of component okra decreased and with delayed in the time of introduction. The lowest grain yield at the two locations were obtained where full population ratio of both crops were intercropped. Intercropping 25 % population of okra with full population of sorghum recorded the lowest fruit yield. Intercropping advantage as measured by land equivalent ratio (LER), land equivalent coefficient (LEC), and monetary advantage index (MAI) indices demonstrated intercropping advantage at all population ratios and time of introduction. The highest value N398, 200.08 was recorded at NCAM location at the population ratio 100S:100 OK and when sorghum was planted two weeks before okra. Planting sorghum two weeks before okra at full population of both crops is recommended for adoption in sorghum/okra intercropping.

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INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is an indigenous crop to Africa in the grass family Poaceae. It is the fifth most important cereal crop in the world (FAOSTAT, 2018). The grain of sorghum is used for food in most parts of sub-Saharan Africa.

Okra (*Abelmoschus esculentus* L. Moench), is an herbaceous annual plant belonging to the family Malvaeceae which are generally grown for their edible immature pods. Okra mucilage is used in industry as a confectionary and for glace paper production (Akinyele and Temikotan, 2007). Okra is also important in the field of medicine as a plasma replacement or blood volume expander (Adetuyi et al., 2008; Kumar et al., 2010).

Intercropping is a traditional farming system that is practiced in most parts of the world (Yilmaz et al., 2008; Lithourgidis et al., 2011). The system is recognized as an important farming system for the development of sustainable food production (Eskandari et al., 2000), particularly in cropping systems with limited external inputs for production. Intercropping can also be used to bring about increased world food production (Addo-Quaye et al., 2011) and ensure sustainable utilization of limited land resources for agricultural production (Tesfa et al., 2001).

Intercropping has the advantage of exploiting environmental resources more efficiently than when the crops are grown separately. Flexibility, maximization of profit, minimization of risk, soil conservation, greater land use efficiency per unit area, control of pests and diseases, weed suppression, and soil fertility improvement are some of the major reasons why intercropping is adopted by small-scale farmers (Banik et al., 2006; Seran and Brintha, 2010; Matusso et al., 2012; Takim, 2012; Degri and Richard, 2014; Afe and Olofintoye, 2013, Isaac et al., 2020). In some cases, however, intercropping has been reported to reduce the productivity of component crops due to intra and inter competitions among components (Afe and Olofintoye, 2013).

The relative time of introduction of a component crop can enhance productivity in crop mixtures. Andrew (1972), Willey (1979b) cited in Addo-Quaye (2011) reported that differential sowing improved productivity and minimizes competition of growth-limiting factors in intercropping since component crops ensure full utilization of growth factors as they occupy the land throughout the growing season. Aggarwal et al. (1992) cited in Oseni (2010) reported that yield reduction in an intercrop was attributed to below and above-ground interaction which is likely to vary depending upon the temporal and spatial differences in the resource use components. The complementary effect that could translate to yield advantage seemed to occur when components of crops have different growing periods such that the demands for natural resources occur at different times. Afe and Olofintoye (2013) opined that the yield reduction in medium maturing cowpea intercropped with maize was largely due to demand for natural resources of cowpea during flowering and podding that coincided with tasselling and silking in maize. Therefore, a proper understanding of resource use as influenced by population density and time of introduction of component crop 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 combination 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), and system productivity index (SPI), monetary advantage (MA) among others have been used to interpret intercropping advantages and competition among component crops in crop mixture. Information on these indices to increase productivity and profitability in sorghum/okra is scanty.

Despite the morphological differences between sorghum and okra, which suggests intercropping advantage there is a paucity of information on sorghum/okra intercropping. The system has not gained popularity among farmers possibly due to the absence of scientific information on the compatibility of okra with sorghum. Although several studies were carried out, these studies did not take into consideration the appropriate population ratio and times of introduction of okra and sorghum for optimal productivity, the economic benefit/profitability of the system was also not mentioned. This present study focuses on the growth and yield of sorghum as influenced by population density and time of introduction of component okra and the intercropping advantage of the system.

MATERIALS and METHODS

Experimental Location and Experimental Design

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 variety (Samsong 49) and okra variety (Clemson) used for the trial were obtained respectively, from Oyo State Agriculture Development Program (OYADP) and the premier seed store in Ilorin.

The experiment consists of six population densities of sorghum and okra (100SH:100OK, 100SH:75OK, 100SH:50OK, 100SH:25OK, 100SH: 00OK, 00SH: 100OK) where SH and OK represented sorghum and okra respectively at three times of introductions; [Same time (ST), two weeks before planting (2WBP) and two weeks after planting (2WAP)]. The experiments were laid out as a 3 x 6 factorial in a randomized complete block design (RCBD) in a split plot. The time of introduction constituted the main plot, while population densities were assigned to the sub-plot treatments.

Land Preparation and Planting

The land was plowed and harrowed twice to obtain a fine tilt. The field was then marked out into blocks. Each plot was 3.0 m x 3.0 m with 1.0 m between blocks and 0.5 m between plots. Okra at four population densities (100%, 75%, 50%, and 25%) combined with sorghum and introduced at three periods (ST, 2WBP, and 2WAP). Pendimenthalin (500 EC) {N-(1- ethyl propyl)-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 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. Lambdacal {(R-cyano- (3-phenoxy phenyl) methyl} (1S, 3S)-3-{(Z)-2-chloro-3, 3, 3-trifluoropropane -1- carboxylate) a systemic insecticide, was applied at the rate of 40 ml/20litres of water as recommended by the manufacturer to the sorghum and okra to prevent insect pests.

N.P.K 20:10:10 was applied to sorghum at 3 and 6 weeks after planting at the rate of 60 kgN/ha and N.P.K 20:10:10 was applied to okra at the rate of 80 kgN/ha at 3 weeks after planting. Sorghum was harvested manually using the knife to cut the panicles from the five tagged plants from the inner rows. The harvested panicles were sundried for three days before threshing to reduce the moisture content to the minimum. Okra was harvested five times manually at four days intervals.

Evaluating Intercropping Efficiency, and Monetary Advantage

The LER which assessed the biological efficiency of intercropping was calculated as proposed by Willey (1979a).

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. Land Equivalent Ratio (LER) values greater than unity were considered advantageous

Land Equivalent Coefficient (LEC) - Measures the interaction and the strength of the relationship was calculated as proposed by Adetiloye et al. (1983).

$$LEC = La \times Lb \quad (1)$$

Where:

La = LER of the main crop a

Lb = LER of intercrop b

For a two-crop mixture, the minimum expected productivity coefficient (PC) is 25%, that is, a yield advantage is obtained if the LEC value exceeds 0.25 and if lesser than 0.25 it is disadvantageous.

The monetary advantage index (MAI) expresses the economic advantage at the intercrop. It was calculated as proposed by Ghosh (2004).

$$MAI = (LER - 1) / LER \quad (2)$$

Thus, if MAI=+, 0 or – indicates, advantage, no difference, and disadvantage respectively. Economic values of sorghum and okra were estimated based on the average prevailing market prices of three main markets at Ilorin during the 2021 cropping season. Respectively, N480.00 /kg and N45.00/kg were the prices of sorghum and okra.

Data Collection and Analysis

The following variables were collected from the five tagged plants at the inner rows of each plot.

Plant height, leaf area, days to 50% flowering and fruiting, the weight of 100 seeds, fruit yield, and grain yield. All the data collected were subjected to analysis of variance (ANOVA) using DSAASTAT. Ver.1.101. (2011). The treatment means were separated using the Duncan Multiple Range Test at a 5% level of probability.

RESULTS and DISCUSSION

The meteorological data during the experiment at the two locations are presented in Tables 1 and 2. The highest rainfall of 39.70 mm and 39.00 mm respectively for NCAM and Malete during the experiment was in September. The mean rainfall was 25.57 mm and 29.33 mm, with the mean temperature ranges between 22.28 – 32.42^{0}C and 21.57 – 30.85^{0}C. The highest relative humidity 88 % and 83 % respectively in August and September were recorded at NCAM and Malete locations.

Table 1. Meteorological data of the experimental site NCAM (June-December 2021)

		Mean Temperature (^{0}C)		
Months	**Rainfall (cm)**	**Minimum**	**Maximum**	**Relative Humidity**
June	35.00	23.00	34.00	81.00
July	23.00	22.00	31.00	77.00
August	23.75	23.00	34.00	88.00
September	39.70	24.00	29.00	84.00
October	14.10	22.00	33.00	85.00
November	17.90	23.00	34.00	77.00
December	-	19.00	32.00	69.00
Total	153.45	156.00	227.00	561.00
Mean	25.57	22.28	32.42	80.14

Source: Lower Niger River Basin Development Authority (Hydrology section) Ilorin, Nigeria

Table 2. Meteorological data of the experimental site Malete (June-December 2021)

		Mean Temperature (0C)		
Months	**Rainfall (cm)**	**Minimum**	**Maximum**	**Relative Humidity**
June	30.00	21.00	32.00	78.00
July	30.00	22.00	31.00	76.00
August	21.00	21.00	30.00	82.00
September	39.00	24.00	29.00	83.00
October	23.00	22.00	31.00	78.00
November	33.00	22.00	31.00	84.00
December	-	19.00	32.00	66.00
Total	176.00	151.00	216.00	547.00
Mean	29.33	21.57	30.85	78.14

Source: Kwara State Agricultural Development Project, Planning, Monitoring and Evaluation Department

The pre-planting physical and chemical properties of NCAM and Malete are presented in Table 3. The textural class of soil at the experimental site is sandy loam (Malete) and loamy sand (NCAM). NPK was generally low with neutral pH at both locations. The organic carbon, total N, and available P at the NCAM location were slightly higher than Malete. Other chemical properties at Malete were higher than NCAM. The total N, available P, and exchangeable Na at the two locations were low.

Table 3. Pre-planting physical and chemical properties of the experimental site

Soil Parameters	**Location**	
	Malete	**NCAM**
Sand	80.0	79.0
Silt	9.0	13.0
Clay	11.0	8.0
Textural class	Sandy loam	Sandy loam
Organic Carbon (%)	0.72	1.21
Total Nitrogen (%)	0.10	0.14
Available Phosphorus (mg/kg)	6.56	6.68
PH	6.80	6.9
Exchangeable Mg (Cmol/kg)	1.19	1.38
Exchangeable K (mg/kg)	0.37	0.24
Exchangeable Ca (mg/kg)	4.25	1.98
Exchangeable Na (Cmol/kg)	0.79	0.70
Exchangeable acidity (Cmol/kg)	0.40	0.30
Mn (mg/kg)	140.0	110.0
Fe (mg/kg)	130.0	98.0
Cu (mg/kg)	1.23	1.04
Zn (mg/kg)	0.90	0.92

The plant height of sorghum at 4, 6, and 8 weeks after planting was significantly influenced by the population density and time of introduction (Table 4). The sole was significantly taller at both locations. At the intercrop, sorghum intercropped with the component okra at the Malete location was slightly taller than the NCAM location. The highest plant height of sorghum was obtained when it was planted two weeks before the component okra. Except at 6 weeks after planting, the height of sorghum at the treatments where okra was planted two weeks ahead of sorghum was significantly shorter compared to other plants.

Table 4. Effect of population density and time of introduction on plant height of sorghum at 4, 6, and 8 weeks after planting

Population Density (PD)	**Plant Height (cm) 4WAP**		**Plant Height (cm) 6WAP**		**Plant Height (cm) 8WAP**	
S:O	**MALETE**	**NCAM**	**MALETE**	**NCAM**	**MALETE**	**NCAM**
100:100	17.26c	13.63d	35.47c	35.03c	68.06c	57.80c
100:75	17.46c	14.56b	38.50b	35.36c	67.13c	61.46b
100:50	18.70b	14.66b	38.46b	35.93bc	68.81c	53.23d
100:25	18.03bc	14.10c	39.80a	37.06b	71.23b	58.73c
100:00	19.83a	15.90a	41.06a	39.28a	75.23a	67.02a
Time of Introduction(TI)						
Same time	17.46b	11.76b	36.55b	38.43b	68.78b	61.20a
2WBP	20.92a	21.00a	37.90a	39.12a	75.02a	61.68a
2WAP	16.40c	10.96c	35.70b	37.86b	66.48c	56.07b
S.E.M	0.2844	0.1362	0.434	0.584	0.578	0.601
PD X TI	*	*	*	*	*	*

Means in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using Duncan's Multiple Range Test. 2WBP= Two weeks before planting, 2WAP= Two weeks after planting, WAP=Weeks after planting, *= Significant

Regardless of population density and time of introduction, stem girth and days to 50% booting were not significantly influenced (Table 5). However, the leaf area of sorghum was significantly influenced by population density and time of introduction. The sole treatment significantly had a higher leaf area than the intercrop at both locations 4816.21 cm and 4023.41cm respectively, for Malete and NCAM. At the intercrop, the lowest leaf area was 2,911.77 cm and 2,975.41 cm respectively for Malete and NCAM were recorded at the component population ratio of 100S:100 OK at both locations. The highest leaf area intercropped at both locations was recorded at the treatment where 25% population of okra was intercropped with the full population of sorghum (100S: 25 OK). Planting sorghum two weeks ahead of okra (2WBP) significantly had more leaf area than other periods of introduction.

Table 5. Effect of population density and time of introduction on leaf area, stem girth, and day to 50 % booting of sorghum

Population Density(PD)	Leaf Area (cm) 10 WAP		Stem Girth (cm) 10 WAP		Days to 50% Booting	
S:OK	**MALETE**	**NCAM**	**MALETE**	**NCAM**	**MALETE**	**NCAM**
100:100	2911.77d	2975.41e	2.00a	1.82a	68.22a	70.33a
100:75	3139.84c	3379.99d	1.95a	1.70a	68.55a	69.00a
100:50	3384.66b	3642.05c	1.94a	1.70a	68.22a	69.22a
100:25	3616.79b	3773.04b	1.92a	1.67a	69.88a	61.77a
100:00	4816.21a	4023.41a	1.91a	1.60a	67.88a	69.77a
Time of Introduction(TI)						
Same time	3051.13b	3315.97b	1.93a	1.82a	69.06a	69.73a
2WBP	3931.65a	4197.77a	1.98a	1.83a	68.40a	69.20a
2WAP	2937.78b	3162.60c	1.92a	1.44a	68.20a	65.13a
S.E.M	40.78	27.36	8.617	6.776	1.801	5.425
PD X TI	*	*	NS	NS	NS	NS

Means in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using Duncan multiple. 2WBP= Two weeks before planting, 2WAP= Two weeks after planting, WAP=Weeks after planting, *= Significant, NS= Not significant.

Generally, the grain yield at the Malete location was slightly higher than at the NCAM location and increased as the population density of the component okra decreased and with further delayed at the time of introduction (Table 6). The grain yield was also found to decrease where okra was planted two weeks ahead of sorghum. The grain yield at the sole was significantly higher than the intercrop population ratios except for 100S: 25 OK at Malete where a similar grain yield was obtained. The lowest grain yield (1534.08 kg/ha and 1327.83 kg/ha) respectively for Malete and NCAM were recorded at the population ratio (100S:100OK), where a full population of the crops was intercropped. The highest grain yield respectively, 2441.25 kg/ha and 1791.40 kg/ha for Malete and NCAM were obtained at the treatment where sorghum was planted two weeks before okra. The lowest grain yield at the two locations was obtained where okra was planted two weeks before sorghum.

Table 6. Effect of population density and time of introduction on panicle length, 100 seeds weight and grain yield of sorghum

Population Density(PD)	Panicle Length (cm)		Weight of 100 Seeds (g)		Grain Yield (kg/ha)	
S :OK	MALETE	NCAM	MALETE	NCAM	MALETE	NCAM
100:100	31.60a	31.50a	2.37	2.31	1534.08d	1327.83d
100:75	31.66a	31.14a	2.35	2.33	1568.46cd	1525.57c
100:50	32.40a	32.38a	2.40	2.36	1708.37c	1647.66b
100:25	32.43a	31.60a	2.42	2.33	2462.17b	1943.76a
100:00	33.58a	31.78a	2.36	2.33	2875.05a	2025.05a
Time of Introduction(TI)						
Same time	32.41a	31.48a	2.40	2.37	1957.84b	1678.05ab
2WBP	33.82a	31.78a	2.38	2.30	2441.24a	1791.40a
2WAP	31.78a	31.14a	2.38	2.34	1689.79c	1612.73b
S.E.M	0.659	1.511	3.360	4.194	51.75	41.05
PD X TI	NS	NS	NS	NS	*	*

Means in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using Duncan multiple. 2WB P= Two weeks before planting, 2WAP= Two weeks after planting, WAP=Weeks after planting, *= Significant, NS= Not significant.

The effect of population density and time of introduction on plant height of okra at 2, 4, 6, and 8 weeks after planting is presented in Table 7. The sole was taller than the intercropped at both locations. At the intercrop, the tallest plant at the two locations was obtained at the treatment population density of 100S:100OK, which is when full populations of the two crops were mixed. Planting okra two weeks before sorghum significantly produced taller plants than when the two crops were sown at the same time (ST) and when sorghum was planted two weeks before okra (2WBP) at 6 and 8 WAP.

Table 7. Effect of population density and time of introduction on plant height of okra at 2, 4, 6, and 8 weeks after planting

Population Density(PD)	**Plant Height(cm) 2 WAP**		**Plant Height(cm) 4 WAP**		**Plant Height(cm) 6 WAP**		**Plant Height(cm) 8 WAP**	
SH:OK	**MALETE**	**NCAM**	**MALETE**	**NCAM**	**MALETE**	**NCAM**	**MALETE**	**NCAM**
100:100	6.36a	6.26a	12.50a	11.10ab	23.61a	28.10a	42.46a	46.73a
100:75	6.16ab	6.23a	11.80ab	11.73a	21.97b	26.50b	39.20c	45.23b
100:50	6.06ab	6.20a	11.46b	10.90b	21.46b	26.00b	37.00d	40.15c
100:25	5.83b	6.13a	10.82b	10.60b	20.93b	24.06c	36.80d	38.21d
00:100	6.40a	6.40a	12.60a	11.73a	22.13ab	26.60b	40.53b	46.13ab
Time of Introduction(TI)								
Same time	6.08a	6.54a	11.80b	10.88a	21.82b	26.64b	38.38b	42.64b
2WBP	6.00a	5.44b	10.94b	10.70a	19.78c	23.44c	35.88c	41.72b
2WAP	6.42a	6.76a	12.81a	11.30a	24.46a	28.68a	43.28a	45.52a
S.E.M	0.152	0.171	0.311	0.269	0.329	0.463	0.329	0.430
PD X TI	*	*	*	*	*	*	*	*

Means in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using Duncan multiple.2WBP= Two weeks before planting, 2WAP= Two weeks after planting, WAP=Weeks after planting, *= Significant

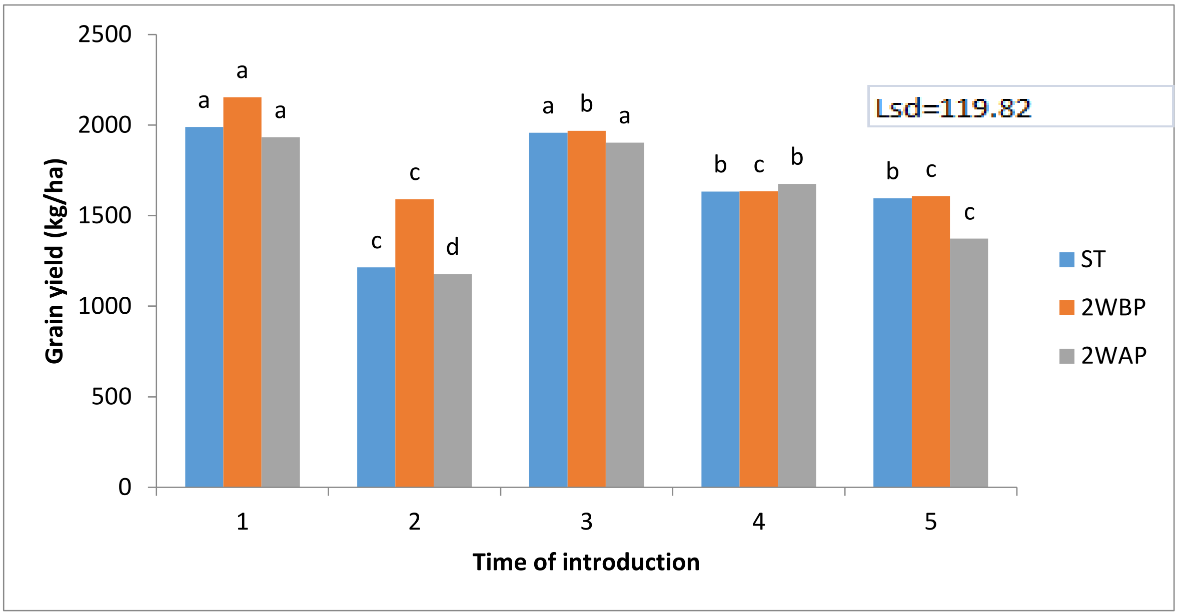
Days to 50% flowering and fruiting, fruit length, and fruit circumference of okra were not significantly influenced by population density and time of introduction (Table 8). Although the treatment where okra was planted two weeks before sorghum (2WAP) had longer and thicker fruits than another period of introduction, it was not significantly manifested.

Table 8. Effect of population density and time of introduction on days to 50% flowering, 50% fruiting, fruit length and fruit circumference of okra

Population Density(PD)	Days to 50 % Flowering		Days to 50 % Fruiting		Fruit Length (cm)		Fruit Circumference (cm)	
SH:OK	**MALETE**	**NCAM**	**MALETE**	**NCAM**	**MALETE**	**NCAM**	**MALETE**	**NCAM**
100:100	51.00	49.88a	50.66	49.77a	10.75	10.81a	7.40	7.47a
100:75	51.00	49.55a	51.44	49.55a	10.13	10.61a	6.88	7.40a
100:50	50.66	49.55a	50.77	49.33a	9.94	10.34a	7.07	7.38a
100:25	51.11	49.00a	51.11	49.22a	9.94	10.17a	6.85	7.01a
00:100	50.77	49.77a	51.11	49.00a	10.81	10.86a	6.98	7.53a
Time of Introduction(TI)								
Same time	51.06	49.33a	51.73	49.53a	10.06	10.74a	6.94	7.42a
2WBP	50.40	50.00a	50.53	49.60a	9.92	9.99a	6.75	7.17a
2WAP	51.26	49.33a	50.80	49.53a	10.94	10.94a	7.43	7.48a
S.E.M	0.768	0.779	0.867	0.566	0.647	0.744	0.483	0.217
PD X TI	NS	NS	NS	NS	NS	NS	NS	NS

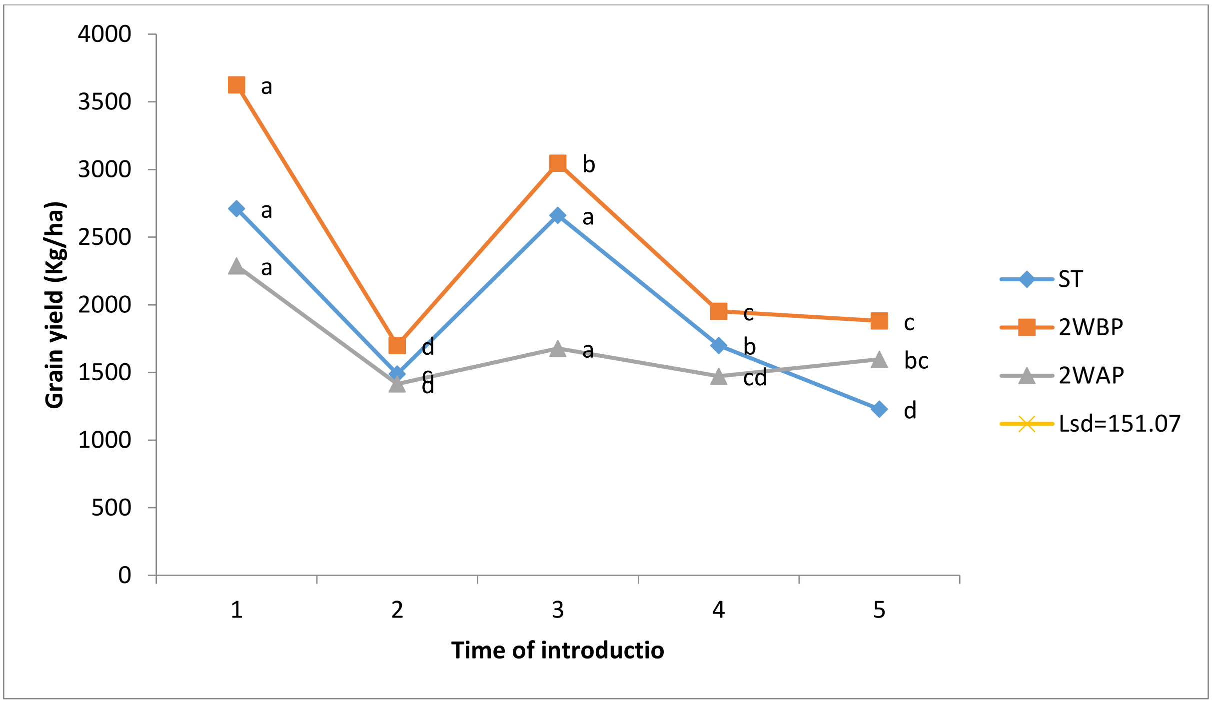
Means in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using Duncan multiple. 2WBP= Two weeks before planting, 2WAP= Two weeks after planting, WAP=Weeks after planting, *= Significant ,NS = Not significant

The interactive effect of population density and time of introduction on grain yield of sorghum and fruit yield of okra are presented in Figures 1-4. The grain and the fruit yield were significantly influenced by population density and time of introduction. Irrespective of time of introduction and locations, the lowest grain yield was obtained at the treatment where full populations of both crops were intercropped (100SH:100 OK). The highest grain yield, 3047.41 kg/ha and 1968.86 kg/ha respectively for Malete and NCAM at the intercrop were obtained at population ratio 100S:25OK when sorghum was planted 2weeks before okra (2WBP). The highest grain yield of the sole was also obtained at this time of introduction.



ST=Same time, 2WBP= Two weeks before planting, 2WAP=Two weeks after planting
1=Sole, 2=100SH:100OK, 3=100SH:250OK, 4=100SH: 50OK, 5=100SH:750K

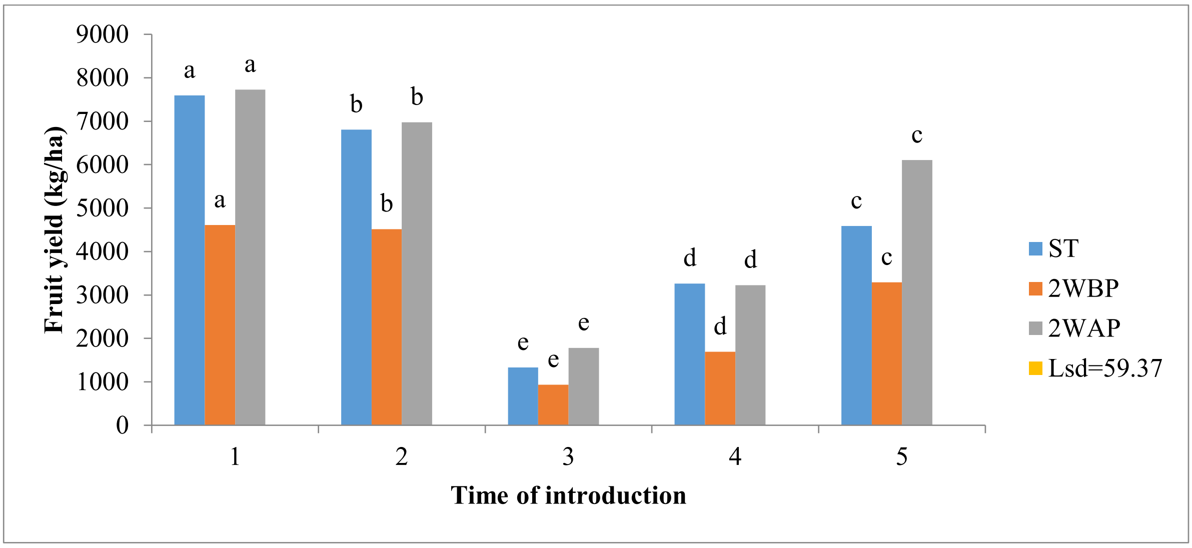
Figure 1. Interactive effect of population density and time of introduction on grain yield of sorghum at NCAM location



ST= Same time, 2WBP=Two weeks before planting, 2WAP=Two weeks after planting,

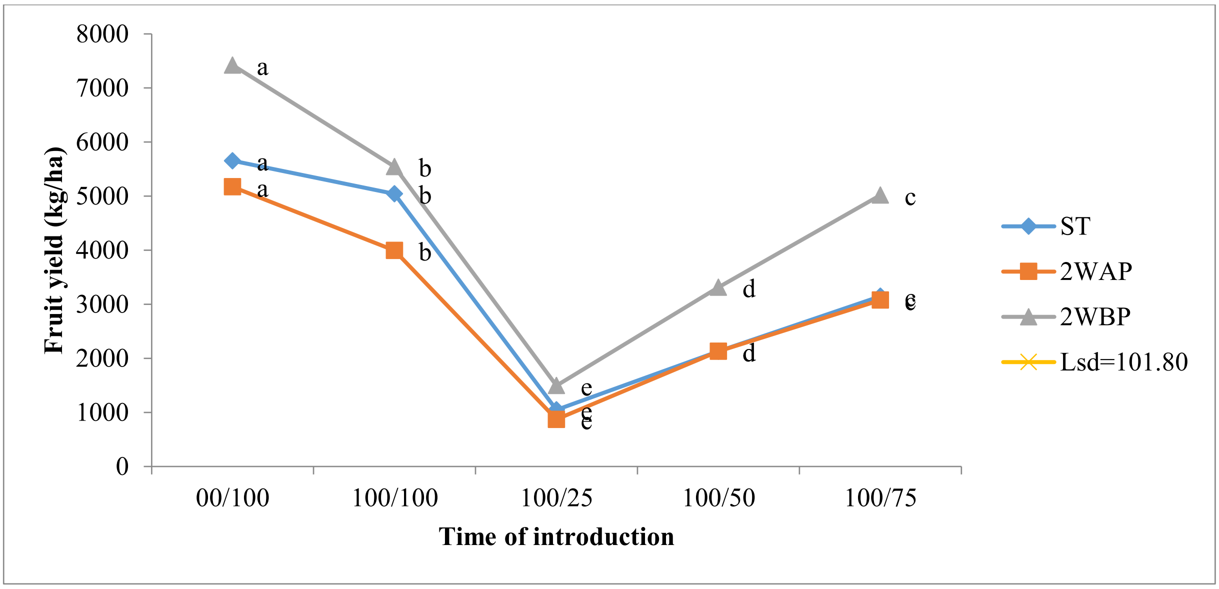
1=Sole, 2=100SH:100OK, 3=100SH:250OK, 4=100SH: 50OK, 5=100SH:750K.

Figure 2. Interactive effect of population density and time of introduction on grain yield of sorghum at Malete location



ST= Same time, 2WBP=Two weeks before planting, 2WAP=Two weeks after planting, 1=Sole, 2=100SH:100OK, 3=100SH:250OK, 4=100SH: 50OK, 5=100SH:750K.

Figure 3. Interactive effect of population density and time of introduction on fruit yield of okra at NCAM location



ST= Same time, 2WBP=Two weeks before planting, 2WAP=Two weeks after planting.

Figure 4. Interactive effect of population density and time of introduction on fruit yield of okra at Malete location

The fruit yield of okra decreased as the population decreased with the highest fruit yield obtained at component population ratio 100S:100OK and the least obtained at 100SH:25OK treatment. Planting okra two weeks ahead of sorghum (2WAP) recorded the highest fruit yield at the two locations.

The efficiency of intercropping in sorghum/okra intercropping as influenced by population density and time of introduction is presented in Table 8. Based on LER and LEC values, the two locations demonstrated intercropping advantage at component population ratios 100SH; 100 OK irrespective of the time of introduction. The values at the NCAM location were found to be higher than the Malete location at all period of introductions. There was no meaningful intercropping advantage at the population ratios 100SH; 50 OK and 100SH: 25 OK at all periods of introduction. Indeed, it was disadvantageous at Malete location at population ratio 100SH:25 OK particularly when sorghum was planted two weeks ahead of okra and population ratio 100SH:25 OK when okra was planted two weeks before sorghum. There was no reasonable intercropping advantage as measured as measured by ATER index at all population ratios tested at the three periods of introduction except at the NCAM location at the population ratio 100SH: 100 OK when sorghum was planted two weeks before okra (2WBP).

DISCUSSION

The nutrient status of the two locations differed and was generally low compared 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 Malete location has been under intensive cultivation over the years (2014- 2021) for Teaching and Research of Farm Practical Training (FPT), whereas, cultivation at the NCAM location commenced about two years (2019-2022). According to Chen et al. (2016), continuous cropping on the same piece of land was identified as a major factor responsible for nutrient loss and soil degradation because the nutrients removed during plant growth for plant physiological processes after harvest were not returned into the soil.

Regardless of population ratio and locations, the sole sorghum was taller with higher leaf area and grain yield than the intercropped. The yield increased as the population of component okra decreased and with further delayed at the time of introduction. This superiority of the sole over the intercropped could be due to 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 earlier researchers Isaac et al. (2020) in sorghum/cowpea intercrop, Ajayi et al. (2020) in okra/legume intercropping; Oseni (2010) in sorghum/cowpea).

The plant height of okra increased with increased plant population and was significantly taller than the sole at the population ratio 100S: 100 OK at 8WAP. A similar response of plant height to population density has been reported by several authors (Rahman et al., 2011; Alani et al., 2018). The increased plant height at a high population ratio could be due to stem elongation (Henderson and Lauer, 2003) with attendance number of nodes/plant (Oh et al., 2007), competitive shading within the leaf canopy architecture (Hiyane et al., 2010) which consequently led to a reduction in the photosynthetic and net assimilation of individual plants (Rahman et al., 2011 cited in Domimqueue and Hrime 1978).

Understanding the appropriate plant population per unit area is one of the main agronomic practices that are required to achieve maximum yield (Sher et al., 2017). According to Orkwor et al. (1991) and Lucas (1992) cited in Ajayi et al. (2020), plant height is the most important feature that determines the competitive ability for light. In the study, it was opined that plant components that attained foliage at a higher canopy layer had better competition for light. From this present study, okra that was planted two weeks ahead of sorghum was taller than those planted at the same time and where sorghum was planted two weeks ahead of okra (2WBP). The leaf area and fruit yield of this treatment were also higher than in other periods of introduction.

The grain yield of sorghum was significantly influenced by population density and time of introduction. The grain yield increased as the population density of component okra decreased. This observation is corroborated by the findings of Oseni, 2010, Karanja et al. (2014), Kunde et al. (2015), and Isaac et al. (2020). The relatively poor yield of sorghum at the component population ratio where the two crops were sown at their full population (100S:100 OK) as observed in this study could be due to overcrowding with the attendant competition for natural resources. The yield reduction was pronounced at the treatment where okra was sown two weeks before sorghum. This observation is expected because okra though, shorter than sorghum the vigorous growth habit exhibited at the earlier stage and with a short maturity date could have given okra an advantage over sorghum to utilize the natural resources better than component sorghum. For instance, the height of okra 43.28 cm and 45.52 cm respectively for Malete and NCAM at 8 WAP was taller than sorghum 35.70 cm and 37.86 cm for Malete and NCAM respectively that was planted at 6 WAP further lending credence to this observation. At this period also, flowering and fruiting had commenced in okra. In the light of the foregoing, however, it is apparent that productivity in sorghum/okra will to a large extent depend on the population ratio and time of introduction employed.

The observed intercropping advantage using LER and LEC indices are consistent with the findings of other researchers Ghosh (2004) in sorghum/groundnut and Oseni and Aliyu (2010), Isaac et al. (2020) in sorghum/cowpea intercropping due to complementarity of the two crops. At high population densities (100S:100 OK and 100S:75 OK) the depressed 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, and that explained why higher intercropping advantage was higher at NCAM than Malete. The intercropping disadvantages at the population ratio of 100S:25 OK were due to a significant reduction in the yield of okra due to a low plant population that could not be compensated for by the yield of sorghum population. Thus, the combined LER and LEC respectively were lower than unity and 0.25.

CONCLUSION and RECOMMENDATIONS

The growth and yield of both crops were influenced by intercropping and to a large extend depended on the population ratio employed and time of introduction. The grain yield of sorghum increased as the population density of okra decreased while the fruit yield of okra decreased as the population decreased and with delayed in the time of introduction. Regardless of population ratio and location, the highest grain yield of sorghum was obtained when it was sown two weeks before okra. Sorghum being a main crop, this period of introduction is recommended for adoption particularly with 75-100 % population of okra for a reasonable intercropping advantage.

Conflict of Interest

The authors have declared no conflicts of interest.

Authors Contribution

AIA conceptualized the work and carried out the data analysis, YLA took the data and wrote the manuscript, and AOA did the field layout.

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