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Performance of Okra [*Abelmoschus esculentus* [L] Moench.*]* as Influenced by Row Arrangement and Weeding Regime Grown in Intercrop with Cucumber (*Cucumis spp.)* in Sudan Savanna

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Field trials were conducted during the rainy season of 2018 and 2019 at the Teaching and Research Farm, Faculty of Agriculture, University of Maiduguri, Borno State, Nigeria, to evaluate the performance of okra in an okra-cucumber intercrop under different row arrangements and weeding regimes in the Sudan savanna agroecological zone. The experiment utilized a factorial

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combination of three-row arrangements of okra and cucumber (1:1, 1:2, and 2:1) and four weeding regimes (W0, W1, W2, and WF) arranged in a split-plot design with three replications. Weeding regimes were assigned to the main plots, while row arrangements were allocated to the subplots.
The study assessed okra parameters including the number of fruits per plant, fruit length, fruit diameter, fruit weight per plant, and yield per hectare. Results revealed that the 1:2 row arrangement produced a higher number of fruits per plant, better fruit weight per plant, and greater fruit yield compared to other arrangements. However, the combination of a 2:1-row arrangement with a weed-free treatment significantly improved fruit yield. In both years and combined mean, the 1:2 row arrangements with weed-free produced the highest monetary return but were not statistically different from the two weddings. The two weddings were therefore optimum for the monetary return of the okra/cucumber mixture. Based on these findings, the 2:1 row arrangement with a weed-free regime is recommended for cultivating okra in an intercrop with cucumber in the Sudan savanna region.

Keywords: Okra; field trials; intercrop; cucumber.

1. INTRODUCTION

"Okra (*Abelmoschus esculentus* [L.] Moench) is a member of the Malvaceae family and is widely valued for its edible green pods. It originates from West Africa, Ethiopia, and Southeast Asia and is cultivated in tropical, subtropical, and warm temperate regions worldwide" (NRC, 2006). Known for its heat and drought tolerance, okra thrives in various soil types, including heavy clay with intermittent moisture, but is sensitive to severe frost. In the southern United States, it is commonly grown in Texas, Georgia, Florida, and Alabama (FAOSTAT, 2012), as well as in home gardens and commercial markets throughout North Carolina (Sanders, 2001).

"World production of okra stood at about 9.4 million tonnes with 69% (5.2 million tonnes) produced in India. As an indigenous crop of Africa, Okra is cultivated widely in Africa for its immature fruits used as a vegetable with a yield of 4.18 million tonnes. In Nigeria, it is estimated at 1.82 million tonnes per year" (FAOSTAT, 2020). "The total area under cultivation has increased over the years. India has been known to be the highest producer of okra in the world, followed by Nigeria and Sudan" (Komolafe, et al., 2021).

Okra thrives well in different soils, but it is best grown in well-drained sandy and clay loam soils, especially with rich organic matter (Sreenivasa, et al*.,* 2010). It can tolerate slightly acidic soil. The crop can be grown in soils with a pH range from 4.5 to 7. According to Iyagba et al. (2012), "okra grows best on loams and sandy loams but will produce good yields on heavier soils. It is a crop of tropical and sub-tropical climates requiring a long warm and humid growing season" (Komolafe, et al., 2021). "It is susceptible to frost and cannot thrive well in cold. It may be grown at elevations from sea level up to 30 m" (Omotoso, et al*.,* 2018) but can tolerate a wide range of rainfall (Omotoso, et al*.,* 2015). "Seeds fail to germinate below 20^{o}C. The optimum temperature for seed germination is 29^{o}C. Okra is a stout, erect annual herb that grows to about 4 m tall with spirally arranged leaves with leaf blades up to 50 cm in diameter" (Olaniyi, et al., 2009). The fruit is a capsule and grows quickly after flowering. Fruits or pods are green, 5-35cm long, and 1-5 cm in diameter (Adetuyi, et al., 2011). The crop is known in many English-speaking countries as 'ladies' finger' or 'ochro' (Remison, 2005). In Nigeria, it is made into soups, stews, and sauces with or without palm oil; fish, and other condiments, or it's boiled as a vegetable. The leaves of okra can also be cooked to make a popular soup called Ilesha in Nigeria (Cooke, 1998). "Okra has a high fiber content which helps to stabilize blood sugar by regulating the rate at which sugar is absorbed in the body system" (Udoh, et al., 2005, Ngok, et al., 2008).

"The adoption of high-yield varieties is emphasized by farmers who still dwell on genotypes with poor yield" (Agba, et al., 2011). "Research studies on okra, point out that, varieties with high-yielding ability should be recommended for food security" (Adetuyi, et al., 2011). "In Nigeria, agricultural production is low due to a lack of proper agronomic practices, and infrastructure, low yields associated with poor soils, and low-yielding and less stable varieties" (Omoregie & Nwajei, 2015). In the study area, crop yield from farmers' fields is low due to soil degradation as a result of oil spillage and exploration (Agba et al, 2011, Umeri, et al, 2018).

With regards to high-yielding crop varieties, there is need to increase effort on research to cultivate new crop varieties that can withstand the harsh environment in future as a means of tackling food insecurity among the populace in this zone. Hence, this study was conducted to evaluate the growth and fruit yield performance of some okra varieties in Agbor located in a rainforest zone of Delta State. The study was to determine the appropriate row arrangement and optimum weeding regime for the maximum performance of okra grown in intercrop with cucumber in the Sudan Savanna region.

2. MATERIALS AND METHODS

Field experiments were conducted during the wet season of 2018 and 2019 at the Teaching and Research Farm, Department of Crop Production, Faculty of Agriculture, University of Maiduguri (Longitude 13°12' 36.02" E and Latitude 11°48' 2.32" N and on an altitude of 354 m above sea level). Maiduguri is in the Sudan Savannah region of Borno State, Nigeria under a semi-arid environment characterized by sparse vegetation with an average annual rainfall of 650mm, spanning 4-5 months (May – September).

The experiment consists of three (3) row arrangements (1:1, 1:2, 2:1) and four (4) weeding regimes (weedy check, hoe weeding once at 3 weeks after sowing (WAS), hoe weeding twice at 3 and 6 WAS, and weed-free). The sole crops of okra and cucumber were also included for the purpose of calculating land equivalent ratio (LER). The weeding regimes were allocated to the main plots while the raw arrangements were allocated to the subplots. The treatments were factorially combined and laid out in a Split Plot Design and replicated three times. There was a total of 36 plots each measuring 3.0 m x 4.5m (gross size of 13.5m^2) while the net plots consist of the three (3) most central rows in each gross plot excluding border rows (6.75m^2). Within replicate block, rows were separated using 1m apart and 2m between each replicate block. The estimated land area used for the experiment was 0.11ha.

Okra (Jokoso) variety was used for the study, which matures in 65 days. The variety is highly remarkable or consumed, a day-neutral, high-yielding, insect and disease-resistant. It has very thick flesh pods, short to medium in height, and deeply lobed leaves arranged spirally on the stem. The local variety of cucumber known as Gurthli was used for the research. Gurthli as a trialling plant is anticipated to control weeds in the intercrop. Okra sowing was carried out on 15 June in 2018 and 25 June in 2019. Cucumber was planted on 29th June in 2018 and 9th July in 2019. The seeds of Okra (Jokoso) were obtained from the Institute of Agricultural Research Samaru, Zaria Nigeria.

The physical and chemical properties of the soil in the experimental site were analysed by taking soil samples at the depths of 0-15cm and 15-30cm(Peech 1965) and analysed in Soil Science Laboratory of University of Maiduguri. The collected sample was composited, air-dried, ground and sieved to pass through 2mm screen before subjecting it to physical and chemicals analyses. The particle size distribution was determined using hydrometer method (Bouyocos, 1962), and P^H meter was used in the determination of soil reaction. Total nitrogen was also determined by kjeldahl digestion method (Bremner & Malvanes, 1982), and spectrometer was used in the determination of P by Bray I–P method (Bray & Kutz, 1945). The organic matter content was also determined using wet oxidation method. Exchangeable bases were extracted in IM NH_4OAc buffed at P^H 79 (Page et al., 1992). While the cation exchange capacity (CEC) was obtained by summation of exchangeable bases (Rhode, 1982). The exchangeable acidity was also determined by KCI extraction method according to Mclean (1965). K and Na: Mg and Ca were determined by flame photometer and atomic absorption spectrophotometer respectively.

Parameters of yield components and yield of okra such as number of fruits harvested per plant, fruit weight per plant (g), fruit length (cm), fruit diameter, and total fruit yield per ha were assessed using standard procedure. Data collected were subjected to analysis of variance and difference between means determined according to Duncan's Multiple Range Test (DMRT) in the General Linear Model (GLM) of SPSS(Gomez and Gomez 1984).

3. RESULTS AND DISCUSSION

The results of the analysis of soil samples taken from the experimental sites are presented in Table The soil of the research site was coarsely textured and well-drained sandy loam at 0-15cm and 15-30cm depth, slightly acidic and low in organic carbon. The soil also has a low cation exchange capacity. Similarly, available phosphorus and Nitrogen were also low. This is

in agreement with Rayer, A.J 1987 who reported that the Sudan savanna soils are low in nutrient status.

The effects of row arrangements and weeding regimes on fruit weight/plants of okra in 2018, and 2019 and the combined mean are presented in Table 1. There was a significant effect of row arrangements on fruit weight/plants of okra in both years and combined mean. The 1:2 row arrangements produced significantly higher fruit weight/plants of okra in both the years and combined mean while the least fruit weight/plants of okra was obtained in 2:1 row arrangements in both years and combined mean. Similarly, there was a significant effect of weeding regimes on fruit weight/plants of okra in both years and combined mean. The two wedding were optimum for fruit weight/plants of okra and the least was observed in weedy check in both the years and combined mean

There was a significant interaction between row arrangements and weeding regimes on okra fruit weight/plants in both years and combined mean (Table 3). The 1:2 row arrangements with two weddings were optimum for fruit weight/plant of okra in both years and combined mean while the least fruit weight/plant was observed in 2:1 with the weedy check.

Table 1. Physico-chemical properties of the surface (0-15) and sub-surface (15-30) soil at the experimental site in Maiduguri during the 2018 and 2019 rainy seasons

Soil Properties	2018		2019	
Particle Size Distribution	**0 – 15**	**15 – 30**	**0 – 15**	**15 - 30**
Sand g/kg	76.00	76.00	76.00	76.00
Silt g/kg	10.00	12.00	10.00	12.00
Clay g/kg	14.00	11.50	16.00	11.00
Textural class	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Chemical composition				
pH in water	6.27	6.27	6.28	6.26
Organic carbon	0.43	0.23	0.42	0.22
Total nitrogen	0.13	0.06	0.13	0.06
Available phosphorus (mg/kg)	3.15	4.90	3.15	3.14
Exchangeable cation (mg/kg)				
K	0.61	0.47	0.61	0.46
Mg	0.60	0.40	0.60	0.41
Ca	1.20	1.00	1.20	1.01
Na	0.13	0.05	0.13	0.06
CEC	2.54	1.92	2.52	1.91

Mg kg = Milligram per kilogram CEC = Cation Exchange Capacity

Table 2. Effect of row arrangements and weeding regimes on fruit weight/plant of okra in Maiduguri during 2018, and 2019 rainy season and combine mean

	Fruits weight/plants (g)		
Treatment	**2018**	**2019**	**Combined mean**
Row arrangement (A)			
1:1	401.04^{a}	290.47^{b}	335.90^{b}
1:2	408.74^{a}	403.02^{a}	405.60^{a}
2:1	352.44^{c}	269.70^{c}	321.57^{c}
SE±	15.05	6.91	14.86
Weeding regimes (B)			
Weedy check	118.79^{c}	102.52^{d}	110.66^{d}
1W	315.08^{b}	209.43^{c}	262.75^{c}
2W	547.19^{ab}	533.53^{ab}	540.36^{ab}
WF	560.95^{a}	542.40^{a}	551.67^{a}
SE±	17.38	9.98	17.11
Interaction (AXB)	*	*	*

**Significant*

Table 3. Interaction between row arrangements and weeding regimes on fruit weight of okra in Maiduguri during 2018, 2019 rainy seasons and combined mean

	Weeding regimes			
	Weedy Check	**1W**	**2W**	**WF**
	2018			
	Row arrangements			
1:1	115.19^{f}	122.29^{e}	360.39^{c}	482.03^{b}
1:2	118.47^{f}	301.29^{d}	591.08^{ab}	623.37^{a}
2:1	73.90^{g}	204.50^{f}	360.40^{c}	521.80^{ab}
SE±		13.82		
	2019			
	Row arrangements			
1:1	120.72^{d}	247.22^{cd}	462.80^{c}	584.29^{ab}
1:2	121.07^{d}	442.94^{c}	571.00^{ab}	648.21^{a}
2:1	114.58^{e}	255.08^{cd}	462.82^{c}	595.28^{ab}
SE ±		30.11		
	Combined Mean			
	Row arrangements			
1:1	118.39^{fg}	229.36^{e}	411.20^{c}	526.92^{ab}
1:2	116.27^{fg}	183.85^{ef}	543.01^{ab}	588.05^{a}
2:1	97.31^{g}	374.99^{d}	477.85^{bc}	585.09^{a}
SE ±		29.72		

Means having the same letters(s) are not statistically different at p ≤ 0.05 (DMRT)

Table 4. Effect of row arrangements and weeding regimes on fruit yield of okra in Maiduguri during 2018, 2019 rainy season and combine mean

	Fruits Yield (t/ha)		
Treatment	**2018**	**2019**	**Combined mean**
Row arrangement (A)			
1:1	4.13^{a}	4.52^{a}	4.32^{a}
1:2	4.28^{a}	4.00^{a}	4.14^{a}
2:1	4.74^{a}	4.65^{a}	4.69^{a}
SE±	0.20	0.21	0.16
Weeding regimes (B)			
Weedy check	0.21^{d}	0.41^{d}	0.31^{d}
1W	1.24^{c}	1.42^{c}	1.33^{c}
2W	5.43^{b}	5.82^{b}	5.63^{b}
WF	6.65^{a}	6.91^{a}	6.78^{a}
SE±	0.24	0.25	0.18
Interaction (AXB)	*	*	*

Means having the same letters(s) are not statistically different at p ≤ 0.05 (DMRT)
**Significant*

The effects of row arrangements and weeding regimes on okra fruit yield in 2018, 2019 and combined mean is presented in (Table 4). There was no significant effect of row arrangements on okra fruit yield in both years and combined mean. There was significant effect of weeding regimes on okra fruit yield in both years and combined mean. The weed free treatment produced the highest okra fruit yield and the least fruit yields was observed in weedy check treatment in both years and combined mean. The interaction between row arrangements and weeding regimes on okra fruit yield in 2018, 2019 and combined means was significant (Table 4). The 2:1 row arrangement with weed free treatment produced significantly higher okra fruit yield in both years and combined mean in the crops mixture (Table 5).

Table 5. Interaction between row arrangements and weeding regimes on fruit yield (t/ha) of okra in Maiduguri during 2018, 2019 rainy seasons and combined mean

	Weeding regimes			
	Weedy Check	**1W**	**2W**	**WF**
	2018			
	Row arrangements			
1:1	0.42^{g}	1.41^{e}	5.49^{c}	6.44^{b}
1:2	0.62^{f}	1.78^{e}	4.27^{cd}	6.24^{b}
2:1	0.58^{f}	1.53^{e}	5.78^{bc}	7.72^{a}
SE ±		0.41		
	2019			
	Row arrangements			
1:1	0.09^{e}	1.78^{d}	5.99^{bc}	6.38^{b}
1:2	0.69^{e}	1.62^{c}	5.24^{bc}	6.31^{b}
2:1	0.45^{e}	1.86^{d}	6.24^{b}	8.05^{a}
SE ±		0.43		
	Combined Mean			
	Row arrangements			
1:1	0.01^{h}	1.28^{g}	5.39^{c}	6.38^{b}
1:2	0.65^{h}	1.63^{fg}	5.25^{c}	6.24^{bc}
2:1	0.25^{h}	1.57^{fg}	6.38^{b}	7.89^{a}
SE ±		0.32		

Means having the same letters(s) are not statistically different at p ≤ 0.05 (DMRT)

"The 1:2 row arrangements with two weeding were optimum for fruits weight/plant in both years and combined mean. The 2:1 row arrangements generally produced lower fruits weight/plant particularly with weedy check. The smaller fruits weight/plant obtained at 2:1 row arrangements combined with weedy check could be due to high population of okra which might have resulted on competition for environmental resources such as nutrient, sunlight and water. In all the years and combined mean, the 2:1 row arrangements with weed free gave the highest okra yield/ha. This is due to high population of the okra in the mixture which resulted in higher yield per unit area. The 1:2 row arrangements with weedy check produced the least okra fruit yield/ha. The low yield recorded in 1:2 row arrangements combined with weedy check could be attributed to low plant population of the okra per plot coupled with intense competition for resources due to the heavy presence of weeds. This finding corroborates with the findings of Jeyakumaram and Seran (2007), and (Akobundu et al 1987) who reported that low plant per unit area leads to low yield of crops". (Bunu, et al. 2024) the present study has shown significantly larger fruits weight/plant from 1:2 row arrangements than the other row arrangements. Essentially this might be due to the fewer populations of okra in the okra/cucumber mixture, the cucumber serving as live mulch. This finding is in agreement with Hamma et al. (2012) who reported that okra fruits weight/plant increased with a decreased plant population. In the present study, there was variation in fruits weight/plant between the years where 2018 had higher fruits weight/plant than in 2019 at 1:2 row arrangements. This could be explained by the variation of rainfall where 2018 had higher rainfall than 2019.

"The okra yield/ha from the present study was significantly favoured by 2:1 row arrangements compared with the other row arrangements. This is expected as the 2:1 row arrangements had higher population of okra in the okra/cucumber mixture. It could also be due to the tall height of plant under 2:1 row arrangements in the present study. Though, they are not statistically different in height due to the different row arrangements but value was higher for 2:1 row arrangements. Although the fruit sizes were smaller for plants grown using 2:1 row arrangements, the higher number of plants/plot from this treatment resulted to higher yield/ha(Adam et al. (2020). This finding is in agreement with Dantata et al. (2020) who reported higher maize yield/ha in 2:1 row arrangements of maize/watermelon mixture compared with 1:1 or 1:2 row arrangements" (Bunu, et al. 2024).

4. CONCLUSION

From the result of the present study, it could be concluded that row arrangements of 1:2 (1 row of okra to 2 rows of cucumber) with weed-free appeared more advantageous to produce okra in okra/cucumber intercrop in the Sudan Savanna agroecological zone of Nigeria.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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