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Biological Efficiency of Okra and *Celosia* Intercrop as Influenced By Inter-Row Spacing

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ABSTRACT

Field experiments were conducted in the Teaching and Research Farm of the Delta State University, Abraka (latitude 5^0 46'N and longitude 6^0 5'E) in early and late planting of 2013/2014. The objective was to determine the optimum inter-row spacing of okra as influenced by okra-Celosia intercrop. The experiment was laid out in a randomized complete block design with nine treatments replicated thrice. Treatments consisted of sole okra at spacing of 100cm x 40cm, 80cm x 40cm, 60cm x 40cm and 40cm x 40cm, okra-celosia intercrop with okra maintaining the same four spacing as in sole okra and sole Celosia. Results obtained showed reduction in vegetative growth and yield of individual crops in the okra-Celosia mixture, compared to when they were planted as sole crops. Maximum land equivalent ratio of 1.90 was obtained with inter-row spacing of 100cm, while land equivalent ratio decreased with lower inter-row spacing. Relative crowing coefficient and aggressivity values obtained indicated that okra was the dominant crop in the mixture. Higher monetary advantage index (₦1900.87 and ₦1999.56) and okra yield equivalent (156.68 and 235.86 kg ha^{-1}) obtained at 60cm inter-row spacing showed that maximum performance of the okra + Celosia production system at this level of inter-row spacing can be obtained.

KEYWORDS: Okra, *Celosia*, okra yield equivalent, land equivalent ratio, Relative crowing coefficient

INTRODUCTION

Efficient utilization and management of on-farm resources are needed for profitable crop production systems that will improve the economic condition of the farmers. Intercropping has been known to be a profitable system since it ensures greater stability of crop yield, efficient harnessing of light and other resources and guarantees efficient land utilization (John and Mini, 2005; Ofosu-Anim and Limbani, 2007), higher economic returns per unit area provides insurance against unstable market prices, and thus reducing the risk of unexpected changes in prices (Sullivan 2001; Gilley, et al. 2002; Ijoyah et al 2015). Okra (*Abelmoschus esculentus* L. Moench) is one of the important vegetable crops cultivated in most agricultural zones of sub-Saharan Africa because of its nutritional value and as an antioxidants (Muoneke and Ndukwe, 2008; Siemonsma, et al. 2004).

Celosia argentea L. is also another leafy vegetable featuring prominently in mixed cropping system in Nigeria for the supply of vitamins and minerals (Martin, 1982; Badra, 1991; Iyagba et al., 2012).

Several researchers have demonstrated important the advantages in intercropping different vegetable crops than sole planting. Such advantages include higher economic returns (Sharaiha and Haddad, 1985; Nursima, 2009; John and Mini, 2005). However, under intercropping, yield production of vegetables grown depends on the crop components selected as well as inter-row spacing. Maximum productivity in vegetable based intercropping could be achieved when inter- and intra-crop competitions are minimized for growth limiting factors and the density is adjusted to reduce competition between intercrop components (Dikwahal et al. 2006). El-Shimi and Amer (2003) observed that okra intercropped with snap beans resulted in reduced crop yield compared with sole okra. Okra in mixture with peas at 2:1 and 1:2 row arrangements also resulted in increased yield over sole crops (Sharaiha and Haddad, 1985). Adeyemi et al. (2014) observed yield advantage of intercropping okra with amaranth, while John and Mini (2005) also observed yield advantage of intercropping okra with amaranth, cucumber, but lower LER were observed with closer spacing.

The study was therefore undertaken to assess the intercrop row spacing under okra + *Celosia* that will result in greater crop yield and provide optimal land use efficiency, which could be useful to farmers.

MATERIALS AND METHODS

Field experiments were conducted in the Teaching and Research Farm of the Delta State University, Abraka (latitude 5^0 46'N and longitude 6^0 5'E) Nigeria within the humid tropical rain forest in April-July (early planting) and August-November (late planting) of 2013 and 2014 seasons. Crops planted were okra *Abelmoschus esculentus* L. Moench (variety NHAE 47-4) and *Celosia argentea* L. (variety TLV 8).

The experiment was laid out in a randomized complete block design having nine (9) treatment combinations replicated thrice within a plot size of 4.8m x 4m (19.2m^2). Treatments consisted of sole okra at spacing of 100cm x 40cm (A_1), 80cm x 40cm (A_2), 60cm x 40cm (A_3) and 40cm x 40cm (A_4), okra-celosia intercrop with okra maintaining the same spacing of 100cm x 40cm (A_1 + C), 80cm x 40cm (A_2 + C), 60cm x 40cm (A_3 + C) and 40cm x 40cm (A_4 + C) and sole

Celosia (C). *Celosia argentea* was maintained at a spacing of 20cm x 20cm in both sole and intercrop. Four weeks old *Celosia* previously in the nursery were transplanted into the field at the rate of one seedling per hole, while okra was planted directly at the rate of two seeds per hole and later thinned to one seed per hole after two weeks. Vegetative growth parameters collected for okra were plant height (from base of plant to the apex), leaf number, stem girth (using veneer calipers) and shoot dry weight (oven drying of 5 plant samples per plot at 65^0C for 48hours) while fruit length, fruit breadth, number of fruits per plant, fruit yield per plant, and fruit yield per plot (t/ha) were yield parameters.

Before the commencement of the first harvest at four weeks after transplanting (4 WAT), five plants per plot were randomly selected to determine vegetative parameters. These include plant height, leaf number, stem girth and number of offshoots. Shoot dry weight was determined by oven drying of another set of plant samples per plot at 65^0C for 48hours. At four weeks after transplanting (4WAT), harvesting of *Celosia* was done by repeated cutting of the stems and offshoots of the plants at 10cm above the ground level. Cumulative fresh shoot marketable yield was determined.

Biological efficiency of okra-celosia intercropping systems was assessed using the following indices:

(i) Land equivalent ratio, LER of each component crop, LER, [where, LER=Y_{ij}/Y_{ii}]

(ii) Land equivalent coefficient, LEC is a product of the LERs of the crop components.

LEC = $[(Y_{ij}/Y_{ii})*(Y_{ji}/Y_{jj})]$ where, Y_{ii} and Y_{jj} are yield of sole crops of okra and *Celosia* respectively, Y_{ij} and Y_{ji}, are yield of intercrops of okra and *Celosia* respectively.

If a value of 1.0 is obtained, it implies that the mixtures are ideally complementary.

(iii) Relative crowding coefficient (RCC) as defined by Willey & Rao (1980)

RCC= K_{ij} x K_{ji}

Where $K_{ij} = [Y_{ij}/ (Y_{ii}-Y_{ij})]$ and $K_{ji}= [Y_{ji}/ (Y_{jj}-Y_{ji})]$, where, K_{ij} and K_{ji} are RCC for okra and *Celosia* respectively.

The crop with the highest coefficient is the dominant crop in the intercrop component.

(iv) Aggressivity index (AI) as defined by (McGilchrist, 1965)

$AI_{ij} = [(Y_{ij}/Y_{ii} \times Z_{ij}) - (Y_{ji}/Y_{jj} \times Z_{ji})]$, Where Y_{ii} and Y_{jj} are yield of sole crops of okra and *Celosia* respectively, Y_{ij} and Y_{ji}, are yield of intercrops of okra and *Celosia* respectively. Zij and Zji are proportion of land area occupied by intercrop relative to sole crops of okra and *Celosia*.

(v) Monetary advantage index (MAI) = Value of combined intercrops yield x (LER-1/LER) where LER is land equivalent ratio. The higher the index value the more profitable the system. The unit price of okra and *Celosia* were N200/kg and N100 per kg on the basis of the market prices.

(vi) Okra equivalent yield as defined by Prasad and Srivastava (1991)

Okra equivalent yield (kgha^{-1}) = (Yield of intercrop/Market price of okra) x market price of intercrop.

Both field and derived data were subjected to analysis of variance (ANOVA) and the least significant difference (LSD) was used for means separation.

RESULTS AND DISCUSSION

Vegetative growth and yield components of okra

The plant height of okra was significantly reduced ($P \leq 0.05$) with decreasing inter-row spacing in both sole okra cropping and in mixture with *Celosia* (Table 1). Lower plant height was observed in okra intercropped with *Celosia* in both early and late cropping. Inter-row spacing of 100cm indicated the highest plant height of 115.18cm and 117.02cm in early and late cropping respectively. Inter-row spacing of 40cm significantly reduced sole okra plant height relative to 100cm inter-row by 30.3% and 29.6% in early and late season cropping respectively, while in the intercropped okra the reduction was 24.4% and 28.9% for same respective seasons.

The number of leaves per plant and stem girth of okra decreased significantly ($P \leq 0.05$) with reduction in inter-row spacing of okra plants in both sole and intercrops (Table 1), however significant reduction was more pronounced with okra plants in mixture with *Celosia*. The least number of leaves (12.33-early, 13.67-late) and stem girth (1.73-early, 1.72-late) in okra plants was observed in intercropped okra with inter-row spacing of 40cm, while sole okra had the highest number of leaves with values of 21.67 and 22.00 in early and late planting. Maximum stem girth of 2.14 (early planting) and 2.30 (late planting) were also observed in sole okra at 100cm inter-row spacing.

Table 1. Vegetative characters of okra as influenced by inter-row spacing and intercropping with *Celosia*

Treatment	Plant height (cm)		Leaf number		Stem girth (cm)		Shoot dry weight (g)	
	early	late	Early	late	early	late	early	late
Sole okra 100 x 40cm	115.18a	117.02a	21.67a	22.00a	2.14a	2.30a	196.15a	201.11a
Sole okra 80 x40cm	110.21a	109.11b	20.67ab	22.33a	2.06a	2.18ab	182.11b	189.17b
Sole okra 60 x40cm	98.72b	100.21bc	20.33ab	20.67a	2.05a	2.21b	180.05c	183.19bc
Sole okra 40 x 40cm	80.31cd	82.33d	18.17ab	19.33ab	1.92b	2.01c	172.61c	180.06bc
Okra (100 x 40cm) + Celosia	90.37bc	93.03c	18.37ab	20.67a	1.93b	1.98c	170.15c	176.21cd
Okra (80 x 40cm) + Celosia	81.60cd	82.16d	17.00b	18.33ab	1.90bc	1.96cd	163.59d	165.11de
Okra (60 x 40cm) + Celosia	78.15cd	76.20d	14.67c	15.00b	1.81bc	1.84de	148.17e	157.21e
Okra (40 x 40cm) + Celosia	68.33d	66.19e	12.33c	13.67c	1.73c	1.72e	120.82f	131.01d
LSD (5%)	14.82	9.11	4.30	4.47	0.19	0.14	10.72	11.33

Means with the same letters within the column are not significantly different (P <0.05)

As presented in Table 1, inter-row spacing had significant effect (P≤0.05) on shoot dry weight of okra plants. Okra shoot dry weight indicated a linear relationship with inter-row spacing. Intercropped okra generally had lower shoot dry weight compared to sole okra. When the sole okra and okra intercropped with *Celosia* were compared, the reduction in shoot dry weight at inter-row spacing of 100cm, 80cm, 60 cm and 40cm were 13.2%, 10.2%, 17.7% and 30.1% respectively during the early cropping and reduction of 12.4%, 12.7%, 14.2% and 27.2% at corresponding inter-row spacing in the late cropping.

The observed decrease in plant height, leaf number, stem girth and shoot dry weight of okra with decrease in inter-row spacing may be due to increased plant population density with lower inter-row spacing. This finding is in agreement with the reports of Muoneke and Mbah (2007) and Ijoyah et al. (2015). They observed reduction in vegetative growth of okra with increasing plant population density. Reducing inter-row spacing from 100cm to 40cm significantly (P≤0.05) reduced fruit length and fruit breadth of okra (Table 2), although reduction was more pronounced in plants intercropped with *Celosia*. Fruit length ranged from 7.19cm to 10.61cm (early planting) and from 7.33cm to 10.72cm (late planting). Maximum fruit breadth of 3.35cm (early planting) and 3.52cm (late planting) were observed in inter-row spacing of 100cm and 80cm respectively.

Table 2. Yield and yield components of okra as influenced by inter-row spacing and intercropping with *Celosia*

Treatment	Fruit length (cm)		Fruit breadth (cm)		No. of fruits/plant (g)		Fruit yield/plant (g)		Fruit yield/plant (t/ha)	
	early	late	early	Late	early	Late	early	late	early	late
Sole okra 100 x 40cm	10.61a	10.72a	3.35a	3.31a	28.67a	29.33ab	600.02ab	611.12ab	12.51e	13.60e
Sole okra 80 x40cm	10.18a	10.13ab	3.17a	3.52a	29.70a	30.00a	615.14a	622.05a	17.23c	19.15b
Sole okra 60 x40cm	9.22b	9.68bc	3.01a	3.23ab	30.63a	30.97a	593.06b	600.18b	20.73a	23.19a
Sole okra 40 x 40cm	8.56b	9.01c	2.90ab	3.01ab	22.17bc	25.67c	339.73e	346.15e	19.65a	20.19b
Okra (100 x 40cm) + Celosia	9.14b	10.21b	2.76ab	2.70abc	25.33b	27.00bc	580.16b	588.83b	12.15e	13.06e
Okra (80 x 40cm) + Celosia	8.00c	7.98d	2.66abc	2.64abc	20.43c	23.67d	436.23c	439.61c	14.63d	15.12d
Okra (60 x 40cm) + Celosia	7.61d	7.70d	2.18bc	2.18bc	16.67d	18.33e	418.06d	421.08d	17.42c	19.11bc
Okra (40 x 40cm) + Celosia	7.19d	7.33d	1.89c	2.00c	10.33e	13.07f	278.61f	280.88f	16.41c	18.06c
LSD (5%)	1.01	0.96	0.78	0.83	3.67	2.83	20.32	15.01	1.18	1.24

Means with the same letters within the column are not significantly different (P <0.05

Sowing okra at inter-row spacing of 40cm under sole or intercropping significantly ($P \leq 0.05$) reduced number of fruits per plant and fruit yield per plant in early and late cropping (Table 2). When compared to inter-row spacing of 100cm, decreasing inter-row spacing to 80cm increased number of fruits and fruit yield per plant, but beyond 80cm, a decreasing trend was observed in sole okra. However in intercrop with *Celosia*, number of fruits and fruit yield per plant consistently decreased with decreasing inter-row spacing. Relative to sole okra, number of fruits of okra in mixture with *Celosia* was observed to have reduced by 11.6%, 31.1%, 45.5% and 35% at 100cm, 80cm, 60cm and 40cm respectively in early planting while a percentage decrease of 7.9%, 21.1%, 40.8% and 49.1% was also observed at the corresponding inter-row spacing in late planting.

Decreasing inter-row spacing significantly ($P \leq 0.05$) increased fresh fruit yield of okra planted alone or intercropped with *Celosia* in both early and late planting (Table 2). In sole okra, reducing inter-row spacing from 100cm to 80cm, 60cm and 40cm, increased fruit yield by 37.7%, 65.7% and 36.3% respectively in early planting, while increase of 40.8%, 70.5% and 48.5% were also observed at the corresponding spacing in late planting. Intercropped okra showed higher reduction in fruit yield relative to sole okra with about 16.5% (early planting) and 17.6% (late planting) when the inter-row spacing was reduced from 100cm to 40cm and 60cm inter-row spacing respectively. Sole okra sown at 60cm inter-row spacing recorded the highest fruit yield of 20.73 t/ha and 23.19 t/ha in early and late planting respectively.

Vegetative growth and yield components of *Celosia*

The plant height, number of leaves and stem girth of *Celosia* were significantly ($P \leq 0.05$) reduced by okra in the intercrop (Table 3), hence sole *Celosia* showed higher values of these vegetative attributes. *Celosia* in late planting generally showed higher performance than early planting. In the intercrop with *Celosia*, the closer the inter-row spacing between okra plants the lower the plant height, number of leaves and stem girth of *Celosia*. *Celosia* introduced into okra reduced plant height by 9.8%, 12.8%, 23.1% and 28.0% at okra inter-row spacing of 100cm, 80cm, 60cm and 40cm in early planting and 12.7%, 11.5%, 22.4% and 26.8% at the corresponding inter-row spacing in late planting. Leaf number and stem girth also showed similar trend with plant height, decreasing in value with reduction in inter-row spacing of okra. The vegetative performance of *Celosia* amidst taller okra plants confirms the reports of other researchers which noted that being a plant which undergoes C_3 cycle photosynthesis it has the capacity for optimally performance under partial shaded conditions (Badra, 1991; Schippers, 2000; Sanni and Adesina, 2012).

Table 3. Vegetative characters of *Celosia* as influenced by inter-row spacing and intercropping with okra

Treatment	Plant height (cm)		Leaf number		Stem girth (cm)	
	early	**Late**	**early**	**Late**	**early**	**Late**
Celosia (sole)	78.24a	80.36a	67.23a	68.12a	2.11a	2.18a
Celosia+ Okra (100 x 40cm)	70.61b	70.15b	55.07b	59.67b	2.00ab	1.98ab
Celosia + Okra (80 x 40cm)	68.20b	71.11b	51.20b	54.23c	1.80ab	1.92ab
Celosia + Okra (60 x 40cm)	60.15c	62.32c	48.67b	48.00d	1.68bc	1.76b
Celosia + Okra (40 x 40cm)	56.33c	58.84c	40.13c	42.33e	1.43c	1.42c
LSD (5%)	6.71	5.11	7.54	5.36	0.34	0.31

Means with the same letters within the column are not significantly different ($P < 0.05$)

Table 4 shows the number of offshoots per plant, shoot dry weight per plant, marketable fresh shoot yield per plant and marketable fresh shoot yield of *Celosia*. Intercropping with okra significantly (P≤0.05) reduced the yield and components of yield of *Celosia.* The highest number of offshoots, shoot dry weight, marketable fresh shoot yield per plant and total marketable fresh shoot yield were obtained in monocrop *Celosia*, while *Celosia* introduced into okra at inter-row spacing of 40cm had the least performance of these attributes. In the early planting, introducing *Celosia* into okra plants, was found to reduce total marketable fresh shoot yield by 6.2%, 13.6%, 22.1% and 28.1% at the respective okra inter-row spacing of 100cm, 80cm, 60cm and 40cm. In the late planting, reduction in total marketable fresh shoot yield of 6.4%, 7.4%, 18.9% and 25.5% was also observed at inter-row spacing of 100cm, 80cm, 60cm and 40cm respectively. Maximum fresh marketable shoot yield 16.11 t/ha was obtained in sole *Celosia*, while the least value of 12 t/ha was obtained in *Celosia* sown with okra (40cm inter-row spacing).

Evaluation of Intercrop Productivity

Intercropping and inter-row spacing significantly influenced land equivalent ratio (LER), land equivalent coefficient (LEC), relative crowding coefficient (RCC) and aggressivity index (AI) in early and late season cropping (Table 5 and 6). The LER at all levels of inter-row spacing were above unity, indicating yield advantage of intercropping for both vegetables. Okra inter-row spacing of 100cm in combination with *Celosia* gave the highest LER of 1.90 (in both planting seasons), indicating that 90% more land would be needed to produce the yield obtained under intercropping conditions.

Table 4. Yield and yield components of *Celosia* as influenced by inter-row spacing and intercropping with okra

Treatment	No. of offshoots/plant		Shoot dry weight (g)		Marketable fresh shoot yield/ plant (g)		Total marketable fresh shoot yield (t/ha)	
	early	late	Early	late	early	late	early	late
Celosia (sole)	21.13a	21.67a	18.53a	19.46a	160.00a	162.19a	15.18a	16.11a
Celosia + Okra (100 x 40cm)	18.27ab	19.00a	13.69b	15.18a	156.12a	150.31a	14.24b	15.08b
Celosia + Okra (80 x 40cm)	16.03b	16.33b	14.05b	14.35b	130.21b	138.88b	13.11c	14.92b
Celosia + Okra (60 x 40cm)	15.67b	16.00b	11.68bc	12.11bc	113.16c	110.12c	11.83d	13.06c
Celosia + Okra (60 x 40cm)	13.00c	13.33c	9.62c	10.83c	86.15d	81.33d	10.92e	12.00d
LSD (5%)	2.44	2.83	3.11	3.02	11.05	13.42	1.01	0.93

Means with the same letters within the column are not significantly different (P <0.05)

Yield advantage of intercropping has been observed in vegetable based intercropping. Olubode et al (2015) reported LER greater than unity in snake tomato/*Celosia*, while John and Mini (2005) obtained 1.77 and 1.91 in wider and closer spacing respectively under okra/amaranth intercrop. LER decreased with lower inter-row spacing. The production coefficient obtained in this study were all above 25% recommended by Adetiloye et al. (1983) for a two crop intercrop. The LEC values which were within the range of 60% (LEC-0.60) and 90% (LEC-0.90) confirms the productivity of the okra-*Celosia* intercrop than sole cropping. The RCC values of okra were generally higher than that of *Celosia*, and decreased with closer inter-row spacing, with higher values in the early planting compared to late planting ranging from 2.56 to 30.25, while the product of both RCCs were above unity, indicating yield advantage. Negative RCC values observed at lower density in a related study on okra+amaranth and okra+cucumber (John and Mini, 2005) were not observed in this study possibly due to closer spacing (20cm x 20cm) of *Celosia* used which allowed for competition between the intercrop components. Values of aggressivity also decreased with closer okra inter-row spacing. All the aggressivity values of okra were positive while that of *Celosia* were negative, indicating that okra was the dominant crop in the intercropping system at all levels of okra inter-row spacing possibly due to its higher canopy. Obasi (1989), Orkwor et al. (1991) and Muoneke and Ndukwe (2008) noted that for a crop to be successful competitor for light, it must have its foliage at a higher canopy layer.

Table 5. Intercrop productivity indices of okra-*Celosia* intercrop as influenced by inter-row spacing

	LER		**LEC**		**RCC**			
Spacing	**early**	**late**	**early**	**late**	**early**		**late**	
					okra	***Celosia***	**okra**	***Celosia***
Okra (100x 40cm) + Celosia	1.90	1.90	0.90	0.90	30.25	15.15	24.19	14.64
Okra (80x 40cm) + Celosia	1.71	1.72	0.73	0.73	5.63	6.33	3.75	12.54
Okra (60x 40cm) + Celosia	1.62	1.63	0.66	0.66	5.26	3.53	4.68	4.28
Okra (40x 40cm) + Celosia	1.56	1.58	0.60	0.62	5.06	2.56	5.45	5.48

Table 6. Intercrop productivity indices of okra-*Celosia* intercrop as influenced by inter-row spacing

Spacing	**AI**				**MAI (₦)**		**Okra equivalent yield (t/ha)**	
	Early		**late**		**early**	**late**	**early**	**late**
	okra	***Celosia***	**Okra**	***Celosia***				
Okra(100x40cm) + Celosia	11.10	-11.10	11.48	-11.48	1820.90	1936.40	156.68	235.86
Okra (80x 40cm) + Celosia	6.73	-6.73	6.15	-6.15	1759.20	1896.72	214.00	228.61
Okra (60x 40cm) + Celosia	5.14	-5.14	4.95	-4.95	1900.87	1999.92	303.46	365.19
Okra (40x 40cm) + Celosia	3.18	-3.18	3.29	-3.29	1570.15	1828.56	269.62	291.04

Profitability of the intercrop system which was assessed through the monetary advantage index (MAI) showed an increasing trend with closer inter-row spacing of the okra plants up to 60cm (Table 6). Maximum MAI of ₦1900.87 and ₦1999.56 in early and late planting respectively at 60cm inter-row spacing. However beyond inter-row of 60cm, a significant reduction in MAI was observed. Decreasing okra inter-row spacing from 60cm to 40cm reduced MAI by 17.4% and 8.6% in early and late cropping respectively, indicating reduction in profitability of the system at that level. The least okra equivalent yield obtained in the okra + *Celosia* intercrop in both seasons was at wider (100cm) inter-row spacing with values of 156.68 and 235.86 kg ha^{-1} indicating that at this inter-row spacing *Celosia* as an intercrop is not suitable in okra production system. The highest MAI and okra equivalent at spacing of 60 x 45cm shows the more economic value of the vegetables and that better utilization of below and above ground resources in the okra+*Celosia* production system can be achieved at this level. Obadoni *et al.*, (2010) and Ahmed *et al.*, (2013) also observed higher economic return from okra in mixture with other vegetables.

CONCLUSION

Results obtained from the study showed reduction in vegetative growth and yield of individual crops in the okra-Celosia mixture, compared to when they were planted as sole crops. Although intercropping depressed growth and yield of the component crops especially at lower inter-row spacing, it resulted in more crop productivity and monetary advantage. It can therefore be concluded that sowing *Celosia* into okra at 60cm inter-row spacing (60cm x40cm) gave the highest monetary advantage index (MAI) and okra yield equivalent. It can therefore be advocated that *Celosia* can be included in okra based production systems at this inter-row spacing without compromising the yield.

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