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RESEARCH ARTICLE

PRODUCTIVITY OF OKRA-MAIZE INTERCROPPING SYSTEM AS INFLUENCED BY VARYING MAIZE PLANT DENSITIES IN MAKURDI, NIGERIA

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ABSTRACT

Field experiments were conducted from June to October during the 2010 and 2011 cropping seasons, at the Research Farm, University of Agriculture, Makurdi, Nigeria, to evaluate the productivity of okra-maize intercropping system as influenced by varying maize plant densities and to assess the advantages of the intercropping system. The treatments consisted of three maize plant densities (33,000, 40,000 and 50,000 plants ha^{-1}) into okra plots, while the sole crops of okra and maize at their recommended plant densities of 33,000 and 40,000 plants ha^{-1} respectively, constituted the fourth and fifth treatments, which also served as controls. The five treatments were replicated four times in a randomized complete block design. The results obtained showed that in okra-maize intercropping system, increasing maize plant density up to 50,000 plants ha^{-1} reduced intercropped okra yield, while the increase in maize plant density significantly ($P \leq 0.05$) increased intercropped maize yield. Maize sown at 50,000 plants ha^{-1} into okra plots, not only recorded the lowest competitive pressure but gave the highest land equivalent ratio (LER) values of 1.83 and 1.86 respectively, in years 2010 and 2011, indicating that greater productivity per unit area was achieved by growing the two crops together than by growing them separately. With these LER values, 45.4 % and 46.2 % of land were respectively saved in 2010 and 2011, which could be used for other agricultural purposes. This study showed that in an okra-maize intercropping system, the optimal maize plant density would be 50,000 plants ha^{-1}. This should therefore be recommended for Makurdi location, Nigeria.

INTRODUCTION

Among the cereals, maize (*Zea mays* L.) ranks third, following wheat and rice in the world production (Kamara *et al*., 2005). In Nigeria, based on the area cropped and quantity produced, maize was the country's third most important cereal crop following sorghum and millet (Uzozie, 2001). Maize is used mainly for human food and livestock feed. In the industry, it is important in the production of starch, oil and alcohol (Kling and Edmeades, 1997). Okra (*Abelmoschus esculentus* L. Moench) is an important vegetable grown in tropical and subtropical parts of the world (Absar and Siddique, 1992). In Nigeria, it is among the foremost vegetable crops in terms of consumption and production area (Iremiren and Okiy, 1999). The immature pods are used as boiled vegetable while its dried form is used as soup thickener (Yadev and Dhanker, 2002). The green pods are rich sources of vitamins, calcium, potassium and other minerals (Lee *et al*., 1990). The cultivation of maize in combination with other crops is a common practice in the tropics (Raji, 2007). About 73 % of the maize in Nigeria is under intercropping (Iken and Amusa, 2004). Poggio (2005) reported that farmers intercropped for varied reasons, including insurance against crop pests, yield increment, weed control and high monetary returns to the farmers. A number of studies have been carried out on monocultured okra and maize as influenced by plant density (Jagtap *et al*., 1998; Ijoyah *et al*., 2010) but these studies, however did not reveal the optimal population density of maize, especially in an okra-maize intercropping system. The experiment was therefore designed to augment the available information.

MATERIALS AND METHODS

The experiments were conducted from June to October, 2010 and 2011 cropping seasons at the Research Farm of the University of Agriculture, Makurdi, Nigeria, to evaluate the productivity of okra-maize intercropping system as influenced by varying maize plant densities. The study location (7^0 $46^/$N, 8^0 $37^/$E) and at an altitude of 228 m above sea level falls within the Southern Guinea savanna agroecological zone of Nigeria. The meteorological information of the area over the trial period is provided in Table 1. The average monthly temperature over the years ranged from 21.0 ^{0}C to 32.4 ^{0}C, while the average relative humidity ranged from 75.2 % to 79.6 %. Mean daily radiation was low throughout the growth period. The month of June recorded the highest amount of rainfall and highest number of rainy days. The variety of okra used was 'Lady Finger' while that of maize was 'Oba 98'. Both varieties of crops are popularly grown by farmers and

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shows good adaptation to the local environment. The experimental area (229.5 m^2) which consisted of sandy-loam soil was ploughed, harrowed, ridged and divided into 20 plots. Each plot consisted of 3 ridges and had an area of 9 m^2. The trial area consisted of five treatments, replicated four times in a randomized complete block design. Three of the treatments consisted of maize sown at the spacing of 1 m x 30 cm, 1m x 25 cm and 1 m x 20 cm, respectively accounting for 33,000, 40,000 and 50,000 maize plants ha^{-1} equivalent into okra plots. Sole okra and sole maize respectively sown at their recommended plant densities of 33,000 and 40,000 plants ha^{-1} (Ijoyah *et al*., 2010; Iken and Amusa, 2004) constituted the fourth and fifth treatments, which also served as the control plots. In the mixture, okra was sown on a single row on top of the ridge, while maize was sown by the side of the ridge, but spaced at the different plant densities. In the sole okra plots, seeds were planted about 2-3 cm deep in a single row on top of the ridges, while in sole maize plots, seeds were sown 2-3 cm deep in a single row by the side of the ridges. Weeding was done manually as the need arose.

The recommended rate of compound fertilizer NPK (15:15:15) for sole maize: 100 kg N ha^{-1}, 40 kg P ha^{-1} and 60 kg K ha^{-1}; for sole okra: mixed fertilizer NPK (15:15:15) at the rate of 100 kg ha^{-1} and for okra-maize mixture: 100 kg N ha^{-1}, 100 kg P ha^{-1} and 100 kg K ha^{-1} were applied (Enwezor *et al*., 1989). The band method of fertilizer application was employed. The fertilizer was applied twice to each plot at 3 and 6 weeks after planting (WAP) for the sole crops and the intercrops. Okra was harvested when the tip of pod was observed to break easily when pressed with the finger tip (Usman, 2001). Maize was harvested at 12 WAP, when the leaves turned yellowish and fallen off which were signs of senescence and cob maturity. Data taken for okra include, days to 50 % flowering, okra plant height at 50 % flowering (measured as the distance in cm from the soil surface to the tip of the top most leaf), number of branches per plant, number of leaves per plant, leaf area (cm^2) taken at 50 % flowering, pod length (cm), pod diameter (cm), number of pods per plant, pod weight (g) and yield (t ha^{-1}). Data taken for maize include, days to 50 % flowering, maize plant height at 50 % flowering (measured as

Table 1. Meteorological information for Makurdi (June-October) 2010, 2011

Year/Month	Average monthly rainfall (mm)	Average monthly temperature (°C)		Mean daily radiation (Cal cm^{-2} day^{-1})	Average relative humidity (%)
		Max.	Min.		
2010					
June	237.0(21)[+]	30.6	22.3	174.3	76.2
July	235.2(20)	30.7	22.7	170.0	76.8
August	225.0(15)	30.5	23.1	175.1	77.4
September	210.0(12)	31.4	21.2	162.3	77.8
October	110.3(7)	32.4	23.3	166.4	75.2
2011					
June	230. 0 (18)[+]	31.2	21.0	170.0	76.4
July	228.4(16)	30.7	21.3	173.5	75.8
August	215.0(14)	30.3	23.0	167.3	79.6
September	198.2(11)	30.0	22.3	164.0	78.0
October	96.0(7)	30.5	21.0	165.1	75.2

[+]Values in parenthesis indicate number of rainy days. Source: Air Force Base, Makurdi Meteorological Station.

Table 2. Yield parameters of okra as influenced by varying maize plant densities in an okra–maize mixture in Makurdi, Nigeria in 2010 and 2011 cropping seasons

Treatments	Days to 50 % flowering (cm)		Okra plant height (cm) at 50 % flowering		Number of branches per plant		Number of leaves per plant		Leaf area (cm^2)		Pod length (cm)		Pod diameter (cm)		Number of pods per plant		Pod weight (g)		Yield (t ha^{-1})	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
SO (33,000)	69.6	68.8	68.3	70.0	12.0	13.5	51.2	58.8	637.5	656.2	11.0	11.3	28.9	27.7	7.5	6.3	45.2	43.6	6.9	6.5
OM (33,000)	69.0	69.5	67.2	65.6	8.8	8.3	32.5	29.5	615.2	610.6	11.0	11.0	27.6	26.8	4.5	4.2	38.0	40.1	5.8	5.4
OM (40,000)	68.5	67.3	67.0	65.3	8.0	7.5	30.0	26.3	605.0	598.8	10.9	11.2	27.3	26.5	4.2	4.0	35.3	38.4	5.3	5.0
OM (50,000)	69.2	69.8	64.4	63.6	7.5	6.3	26.8	23.8	600.2	594.0	10.6	10.9	26.0	26.7	3.6	3.8	34.0	37.8	5.0	4.7
Means	69.1	68.9	66.7	66.1	9.1	8.9	35.1	34.6	614.5	614.9	10.9	11.1	27.5	26.9	5.0	4.6	38.1	40.0	5.8	5.4
LSD ($P \leq 0.05$)	10.2	9.7	10.2	21.6	3.0	2.9	15.2	19.9	18.2	20.1	1.2	0.8	3.2	1.5	2.8	2.0	5.1	3.0	1.0	0.8
Cv(%)	7.4	8.9	18.0	20.4	15.0	20.7	10.7	15.3	10.5	17.4	8.2	4.5	5.0	3.5	10.3	21.6	9.4	14.6	12.5	19.8

SO : Sole okra sown at 33,000 plants ha^{-1}. OM (33,000) : okra intercropped with maize sown at 33,000 plants ha^{-1}.
OM (40,000): Okra intercropped with maize sown at 40,000 plants ha^{-1}. OM (50,000): Okra intercropped with maize sown at 50,000 plants ha^{-1}.

Table 3. Yield parameters of maize as influenced by varying maize plant densities in an okra–maize mixture in Makurdi, Nigeria in 2010 and 2011 cropping seasons.

Treatments	Days to 50 % flowering		Maize plant height (cm) at 50 % flowering		Number of leaves per plant		Number of cobs per plant		Cob length (cm)		Cob diameter (cm)		Cob weight (g)		Yield (t ha^{-1})	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
SM (40,000)	48.2	49.3	132.0	129.6	13.5	12.3	1.4	1.5	16.2	15.8	15.8	14.7	325.0	327.5	4. 5	4.0
OM (33,000)	53.0	52.0	130.3	126.2	12.0	12.3	1.2	1.0	15.0	14.3	14.7	14.1	310.0	298.3	2.6	2.3
OM(40,000)	53.2	53.3	139.0	144.6	12.0	12.3	1.3	1.4	15.6	14.8	13.2	13.1	315.2	304.3	3.0	2.8
OM(50,000)	48.2	53.0	140.2	134.2	13.7	12.3	1.6	1.9	16.7	15.0	13.0	12.4	332.0	329.5	5.0	4.5
Means	50.7	51.9	135.4	133.6	12.8	12.3	1.4	1.5	15.9	15.0	14.2	13.5	320.6	317.4	3.8	3.9
LSD ($P \leq 0.05$)	3.0	2.3	15.6	19.2	2.3	0.8	0.7	0.3	3.2	1.6	5.3	3.9	8.3	20.4	1.4	1.1
Cv(%)	6.2	4.0	10.3	8.9	7.0	4.3	5.3	2.9	8.5	6.7	8.3	4.3	13.0	16.1	10.5	17.2

SM : Sole maize sown at 40,000 plants ha^{-1}. OM (33,000): okra intercropped with maize sown at 33,000 plants ha^{-1}.
OM (40,000): Okra intercropped with maize sown at 40,000 plants ha^{-1}. OM (50,000): Okra intercropped with maize sown at 50,000 plants ha^{-1}.

Table 4. Land equivalent ratio (LER), Competitive ratio (CR) and Percentage (%) land saved from intercropping okra and maize sown at varying plant densities in 2010 and 2011 cropping seasons.

	Sole crop yield (t ha^{-1})				Intercrop yield (t ha-1)				Okra – Maize mixture									
	Sole okra		Sole maize		okra		maize		LER		Lo		Lm		CR		% Land saved	
Treatments	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Soles	6.9	6.5	4.5	4.0	-	-	-	-	-	-		-	-		-	-	-	-
OM(33,000) -	-	-	-		5.8	5.4	2.6	2.3	1.42	1.41	0.84	0.83	0.58	0.58	1.45	1.43	29.6	29.1
OM (40,000)	-	-	-	-	5.3	5.0	3.0	2.8	1.44	1.47	0.77	0.77	0.67	0.70	1.15	1.10	30.6	32.0
OM (50,000)	-	-	-	-	5.0	4.7	5.0	4.5	1.83	1.86	0.72	0.73	1.11	1.13	0.65	0.65	45.4	46.2

Soles : Sole crops of okra and maize sown at their recommended plant densities. OM (33,000): okra intercropped with maize sown at 33,000 plants ha^{-1}. OM (40,000):Okra intercropped with maize sown at 40,000 plants ha^{-1}. OM (50,000): Okra intercropped with maize sown at 50,000 plants ha^{-1}.

$$\text{LER} = \frac{\text{Intercrop yield of crop A}}{\text{Sole crop yield of Crop A}} + \frac{\text{Intercrop yield of crop B}}{\text{Sole crop yield of Crop B}}$$

Lo, Lm = Partial LER of component crops

$$\text{CR} = \frac{\text{Lo}}{\text{Lm}}$$ (Division of the partial land equivalent ratios of the component crops)

% land saved = 100 -1/ LER x 100

the distance in cm from the soil surface to the collar of the top most leaf), number of leaves per plant, number of cobs per plant, cob length (cm), cob diameter (the diameters at the head, centre and tail ends of the cob were measured in cm and averaged). The cobs were weighed using an electronic weighing balance to obtain cob weight (g). The cobs were later shelled manually and the total grains for each plot weighed to obtain the yield (t ha^{-1}). All data were statistically treated using the Analysis of variance (ANOVA) for randomized complete block design and the Least Significant Difference (LSD) was used for mean separation ($P \leq 0.05$) following the procedure of Steel and Torrie (1980). The land equivalent ratio (LER) was determined as described by Willey (1985) using the formula:

$$\text{LER} = \frac{\text{Intercrop yield of crop A}}{\text{Sole crop yield of A}} + \frac{\text{Intercrop yield of crop B}}{\text{Sole crop yield of B}}$$

The competitive ratio (CR) as described by Willey and Rao (1980) was determined using the formula: CR= Lo/Lm Zo/Zm, where Lo: Partial LER for okra; Lm: Partial LER for maize; Zo and Zm: are the sown proportion of okra and maize respectively.
The percentage (%) land saved as described by Willey (1985) using the formula:

% Land saved= 100- 1/LER x 100.

These calculations were used to assess the advantages of the intercropping system.

RESULTS AND DISCUSSION

The yield parameters of okra as influenced by varying maize plant densities in an okra-maize mixture in 2010 and 2011 is given in Table 2. Days to attain 50 % flowering and plant height of okra taken at 50 % flowering were not significantly ($P \leq 0.05$) affected by increasing maize plant density. Monocropped okra at its recommended plant density of 33,000 plants ha^{-1} gave the highest number of branches per plant, number of leaves per plant and leaf area, significantly ($P \leq 0.05$) greater than those obtained from intercropped okra with maize sown at varied plant densities. This view agreed with Silwana and Lucas (2002) who reported that intercropping reduced vegetative growth of component crops. Muoneke and Asiegbu (1997) also reported that high plant density of maize reduced number of okra leaves due to competition for light and other growth resources.

Although, increasing maize plant density did not significantly ($P \leq 0.05$) affect pod length and pod diameter, however, increase in maize plant density up to 50,000 plants ha^{-1} significantly ($P \leq 0.05$) reduced number of pods per plant, pod weight and yield compared to monocropped okra at its recommended plant density. The progressive reduction in number of pods, pod weight and yield could be due to the depressing effect of high plant density of maize and the interspecific competition of the component crops in mixture. In addition, shading by taller maize plants in mixture could have reduced the photosynthetic rate of okra (a lower growing plant), thereby reducing pod weight and yield. Higher yield in sole cropping over intercropping had been reported by Olufajo (1992) and Muneer *et al*., (2004). The yield parameters of maize as influenced by varying maize plant densities in an okra-maize mixture in 2010 and 2011 cropping seasons is given in Table 3.

It took longer days for maize under intercropping with okra to attain 50 % flowering when compared to monocropped maize. The intense overcrowding of the intercrops could have prompted competitive demands on available nutrients and moisture, thus prolonging days to attain 50 % flowering for maize. Increasing maize plant density does not significantly ($P \leq 0.05$) affect days to attain 50 % flowering for intercropped maize. Increasing maize plant density did not significantly ($P \leq 0.05$) affect maize plant height taken at 50 % flowering and number of leaves per plant. Under intercropping, number of cobs per plant significantly ($P \leq 0.05$) increased as maize plant density increased. The greatest number of cobs per plant was produced from intercropped maize sown at 50,000 plant ha^{-1}. This might be due to the more efficient use of basic resources and the complimentary effect of the component crops in the mixture. This view agreed with Ogindo and Walker (2005) who reported that improvement of water use efficiency in intercropping leads to greater use of other resources.

Although cob length and cob diameter of intercropped maize were not significantly ($P \leq 0.05$) affected by increasing maize plant density, however cob weight and grain yield obtained from intercropped maize reduced as maize plant density increased. The greatest grain yield was obtained when intercropped maize was sown at the maximum density of 50,000 plants ha^{-1}. This might be linked to the greatest number of cobs produced. Increasing maize plant density up to 50,000 plants ha^{-1} significantly ($P \leq 0.05$) increased grain yield of intercropped maize by 48.0 % and 48.9 % respectively, in years 2010 and 2011 compared to that obtained from intercropped maize sown at 33,000 plants ha^{-1} and by 40.0 % and 37.8 % respectively, in years 2010 and 2011 compared to that produced from intercropped maize sown at 40,000 plants ha^{-1}. Olufajo (1992) reported that in maize/soybean intercrop, increasing maize plant density increased maize yield significantly.

In both years, land equivalent ratio (LER) values increased with increase in maize plant density (Table 4). This agreed with reports of Prasad and Brook (2005) and Muoneke *et al*., (2007) who reported that LER increased at higher plant density. The LER values of okra were all above 1.00, signifying that it is advantageous to have both crops in intercropping. This could be due to greater efficiency of resource utilization in intercropping. Mohta and De (1980) reported that LER increased to maximum of about 48.0 % by intercropping compared with the cereal sole crops. Intercropping okra with maize sown at 50,000 plants ha^{-1} gave the highest LER values of 1.83 and 1.86 respectively, in years 2010 and 2011, indicating that greater productivity per unit area was achieved by growing the two crops together than by growing them separately. With these LER values, 45.4 % and 46.2 % of land were saved respectively, in 2010 and 2011, which could be used for other agricultural purposes. In okra-maize mixture, competitive pressure reduced as maize plant density increased. The lowest competitive pressure was recorded when maize was sown at 50,000 plants ha^{-1} into okra plots, indicating that at this level, both crops were highly complementary and most suitable in mixture. This view agreed with Fisher (1977) who reported that LER greater than one, could be due to greater efficiency of resource utilization in intercropping prompted by increased plant density.

CONCLUSION

From the results obtained, it can be concluded that in okra-maize mixture, increasing maize plant density up to 50,000 plants ha^{-1} reduced intercrop okra yield, while the increase in maize plant density up to 50,000 plants ha^{-1} significantly ($P \leq 0.05$) increased intercropped maize yield. Both crops were found to be highly complementary and most suitable in mixture when maize was sown at 50,000 plants ha^{-1} into okra plots. This is associated with the lowest competitive pressure, highest land equivalent ratio values and greatest percentage of land saved. It is however, recommended that further investigation be done to evaluate a wider range of okra and maize varieties in intercrop and across different locations within the Guinea savannah agroecological zone of Nigeria.

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