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EFFECT OF PLANT POPULATION AND SPATIAL ARRANGEMENT ON THE PRODUCTIVITY OF OKRA/*AMARANTHUS* INTERCROPPING SYSTEM

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ABSTRACT
Two field experiments laid out in randomized complete block design were conducted during 2004 and 2005 wet seasons at the Michael Okpara University of Agriculture, Umudike, Umuahia to investigate the effects of Amaranthus plant population and spatial arrangement on the growth, yield and productivity of okra/amaranth intercropping system. Okra and amaranth were each planted in monoculture or intercropped between or within rows at either 55,550 or 111,110 plant s ha^{-1} of Amaranthus. The results indicated that intercropping reduced the growth and yields of okra and Amaranthus relative to their sole crops. Okra depressed the growth and yield of Amaranthus. Comparative assessment of the mixture suggested that it was better to grow the two crops separately. There were yield disadvantages of growing them together, especially with the higher Amaranthus population either between or within okra rows where there were 37 or 39% (2004) and 38 or 41% yield disadvantage (2005), respectively as depicted by land equivalent ratio (LER) of 0.63 or 0.61 (2004) and 0.62 or 0.59 (2005), respectively. Only slight yield advantages of about 8% in 2004 and 6% in 2005 cropping seasons were achieved with 55,550 Amaranthus plants ha^{-1} intercropped between okra rows. This could not compensate for difficulties in cultural operations when crops were intercropped.

Keywords: Okra, *Amaranthus*, Plant population, Intercropping, Spatial arrangement

INTRODUCTION
Intercropping, which is the simultaneous cultivation of two or more crops on the same piece of land is the predominant practice in traditional farming systems of the tropics, including Nigeria (Fawusi, 1985). The crops may be sown at the same or different times (with considerable overlap in time) depending on the farmer's preference (Remison, 1982: Ofori and Stern, 1987). The predominant practice of mixed intercropping in the developing countries including Nigeria indicated that farmers have refused to adopt the sole cropping technology packages. The reasons for practicing mixed intercropping include the production of higher total yields from a given area of land, insurance against crop failure, reduction in the levels of insect pests, diseases and weeds and better use of growth resources among others (Okigbo and Greenland, 1976; Willey, 1979, Okpara and Omaliko, 1995). There is, therefore, need to investigate the potentials of intercropping and suggest ways of improving the system and achieving high yield through the system.

Huxley and Maingu (1978) had suggested that maximum productivity in intercropping could be achieved when inter- and intra-crop competitions are minimal for growth limiting factors and the density of each crop adjusted to minimize competition between them.

Okra (*Abelmoschus esculentus* L. Moench) and vegetable amaranth (*Amaranthus hybridus* L.) are among vegetables featuring prominently in mixed cropping system in Nigeria for the supply of vitamins and minerals for man and his livestock.

Information is scanty on okra/vegetable amaranth system, especially with regard to planting density and planting pattern of the component crop species. The objective of this work was to evaluate the suitable amaranth planting density and planting pattern, and also the productivity of okra/vegetable amaranth intercropping system at Umudike.

MATERIALS AND METHODS

Two field experiments were conducted during the wet seasons of 2004 and 2005 on an ultisol of Michael Okpara University of Agriculture, Umudike (latitude 05º 28′ N, longitude 07º 32′ E, 122 m above sea level). Umudike, a humid environment has average rainfall of about 2200 mm per annum. During the periods of the experiments (April-August) in each year, the total rainfalls were 1245.3 mm (2004) and 1305 mm (2005) while the mean minimum and maximum temperatures were 22.4º and 30.6º C (2004) and 22.6º and 30.8º C (2005), respectively. The physicochemical properties of the upper 15 cm of the soil profile of the experiment sites were pH soil: water 5.28 and 5.45, total N 0.126 and 0.083%, available P 11.60 and 11.90 ppm, sand 77 and 80%, silt 11.60 and 11.90%, and clay 11.40 and 8.10% for 2004 and 2005, respectively. The soils were sandy loam.

The land was ploughed, harrowed and marked out into plots 2.4 m x 2.4 m in each year. Well decomposed poultry manure at the rate of 10 t ha^{-1} was incorporated into each plot two weeks before planting okra.

The experiments were laid out in randomized complete block design (RCBD). There were seven treatments with three replicates (blocks). The treatments were: sole okra, sole amaranth 55,550 plants ha^{-1}, sole amaranth 111,110 plants ha^{-1}, okra within amaranth 55,550 plants ha^{-1}, okra between amaranth 55,550 plants ha^{-1}, okra within amaranth 111,110 ha^{-1} and okra between amaranth 111,110 plants ha^{-1}. The sole crops were included in the treatments for the assessment of the productivity of the intercropping systems.

Okra (*Abelmoschus esculentus* l. Moench) cv 'Awgu Early' and vegetable amaranth (*Amaranthus hybridus*) cv 'Large Green' were intercropped. Okra was seeded two per hole on 8 May 2004 and 10 May, 2005 at the spacing of 60 cm x 30 cm and the seedlings were thinned to one plant stand $^{-1}$ two weeks after planting (WAP) in both sole and intercropped plots. In the intercropped plots, amaranths were spot planted three weeks after okra within and between okra rows, also at 60 cm x 30 cm. Later the amaranths were thinned to one plant stand $^{-1}$ for 55,550 plants ha $^{-1}$ population and two plants stand $^{-1}$ for 111,110 plants ha $^{-1}$ population.

Four hundred kilograms ha $^{-1}$ of NPK 15:15:15 fertilizer were applied in bands 4 WAP amaranth or 7 WAP okra. During the experiments, hand weeding was done thrice. Insect pests were controlled using karate 2.5 EC at 12 ml in 4.2 l of water according to the manufacturer's recommendation.

Table 1: Okra plant height, days to 50% flowering, number of leaves and leaf area index as influenced by amaranth planting density and planting pattern in okra/amaranth intercropping system in 2004 and 2005 wet seasons.

Cropping systems	Days to 50% Flowering		Plant height (cm)		No. of leaves Plant ha^{-1}		Leaf area index	
	2004	2005	2004	2005	2004	2005	2004	2005
Okra sole	59.33	56.62	63.33	60.24	12.18	10.25	1.51	1.42
Okra b/w 55,550 amaranth plants ha $^{-1}$	57.00	56.31	40.57	43.51	9.06	8.11	1.06	1.07
Okra b/w 111,100 amaranth plants ha $^{-1}$	60.00	57.42	48.60	47.24	7.79	7.60	0.86	0.78
Okra within 55,550 amaranth plants ha $^{-1}$	54.33	55.10	43.93	42.51	8.13	8.22	1.01	1.18
Okra within 111,100 amaranth plants ha $^{-1}$	60.00	54.20	37.93	40.60	8.14	7.31	1.01	1.00
$LSD_{0.05}$	Ns	Ns	15.16	12.25	2.13	1.36	0.150	0.281

Table 2: Number and weight of okra fresh pods/ plant and fresh pod yield as influenced by amaranth planting density and planting pattern in okra/amaranth intercropping system in 2004 and 2005 wet seasons.

Cropping systems	No. of fresh pods (plant $^{-1}$)		Wt. of fresh pods (g plant $^{-1}$)		Fresh pod yield (kg ha^{-1})	
	2004	2005	2004	2005	2004	2005
Okra sole	15.89	14.26	141.57	142.79	8023.60	7924.91
Okra b/w 55,550 amaranth plants ha $^{-1}$	7.28	8.55	131.55	119.94	7301.18	6656.92
Okra b/w 111,100 amaranth plants ha $^{-1}$	6.22	6.18	59.27	61.40	3489.68	3407.72
Okra within 55,550 amaranth plants ha $^{-1}$	5.69	5.34	127.22	107.09	7060.77	5943.68
Okra within 111,100 amaranth plants ha $^{-1}$	5.61	5.25	67.94	59.97	3771.09	3328.46
$LSD_{0.05}$	3.295	4.621	26.242	20.261	350.213	400.302

Data collected for okra were days to 50% flowering, plant height at 9 WAP, and number of leaves plant $^{-1}$ at 9 WAP, leaf area index (LAI) at 9 WAP, number of fresh pods plant $^{-1}$, fresh pod yield ha $^{-1}$; for amaranth, they were plant height 9 WAP, number of branches plant $^{-1}$ at 9 WAP, number of leaves plant $^{-1}$ at 9 WAP, LAI, edible leaf and marketable yields ha $^{-1}$. The leaf area of okra ($Y = - 0.211 + 0.6X$, $r = 0.98^{**}$), Muoneke *et. al.*, 1997) and amaranth ($Y = 0.134 + 0.824$, $r = 0.95^{**}$), derived by tracing fifty leaves of varying growth stages on metric graph papers). In each case, Y = leaf area while X was the product of the length and widest breath of each leaf. The total leaf areas plant $^{-1}$ were divided by feeding area of each plant to give the LAIs of the crops.

The data for each crop were separately statistically analysed according to the procedure for RCBD (Gomez and Gomez, 1984) and significant treatment mean differences were determined according to Fisher's protected least significant difference ($F\text{-}LSD_{0.05}$). Land equivalent ratio (LER) (the sum of the ratios of the yields of the intercrops to those of the sole crops, Fisher, 1977: Mead and Willey, 1980) was used to determine the productivity of the intercropping systems.

RESULTS

Okra growth and yield

There was no significant difference ($P > 0.05$) among the cropping systems in okra attainment of 50% flowering in both 2004 and 2005 cropping seasons (Table 1). Okra attained 50% flowering 54-60 DAP. Okra plant height, numbers of leaves plant $^{-1}$ and leaf area index (LAI) were reduced by intercropping. However, among the intercrops, the plant height and leaf production were similar. There were no effect of planting pattern nor amaranth plant population on these growth attributes. When okra was intercropped within amaranth plants there was no amaranth plant population effect on okra LAI but when grown between amaranth plants, the LAI was higher with intercropping between 55550 than 111000 amaranth plants ha^{-1} in both years. Intercropping reduced the number and weight of fresh pods plant^{-1} as well as fresh pod yield ha^{-1} relative to the sole crop (Table 2). Among the intercrops, fresh pod production and weight plant^{-1} were similar within the planting pattern and amaranth populations in both years. Irrespective of planting pattern, fresh pod weight plant^{-1} was higher with intercropping at lower than with higher amaranth plant population in both years. In 2004, within amaranth plant population, there was no significant ($P > 0.05$) effect of planting pattern on okra yield but irrespective of planting pattern, fresh pod yield was higher with intercropping okra with lower than higher amaranth population. The trend was the same in 2005, except that at lower amaranth population (55500 plants ha^{-1}), between planting pattern intercropping gave higher yield than within planting pattern.

Table 3: Plant height, number of branches, number of leaves and leaf area index of amaranth as influenced by amaranth planting density and planting pattern in okra/amaranth intercropping system in 2004 and 2005 wet seasons.

Cropping systems	Plant height (cm)		No. of branches plant ha^{-1}		No. of leaves plant ha^{-1}		Leaf area index	
	2004	2005	2004	2005	2004	2005	2004	2005
Sole amaranth 55,550 plants ha^{-1}	53.61	52,62	2.02	2.10	33.57	32.26	1.21	1.22
Sole amaranth 111,100 plants ha^{-1}	51.81	50.46	2.34	2.24	32.15	30.18	1.20	1.02
Okra b/w 55,550 amaranth plants ha^{-1}	25.61	30.24	0.47	1.02	17.21	18.25	0.58	0.63
Okra b/w 111,100 amaranth plants ha^{-1}	25.34	26.21	0.59	0.60	13.36	15.22	0.42	0.54
Okra within 55,550 amaranth plants ha^{-1}	20.34	25.21	0.50	0.53	11.29	12.43	0.22	0.35
Okra within 111,100 amaranth plants ha^{-1}	18.93	19.75	0.47	0.42	9.26	10.26	0.20	0.26
$LSD_{0.05}$	8.260	5.212	0.102	0.201	4.051	9.242	0.621	0.416

Amaranth growth and yield.

In sole amaranth, plant population did not significantly ($P > 0.05$) affect plant height, number of leaves plant^{-1}, number of branches plant^{-1} and leaf area index in both 2004 and 2005 cropping seasons (Table3). Intercropping amaranth with okra irrespective of amaranth plant population and planting pattern significantly ($P < 0.05$) reduced amaranth growth attributes. Among the intercrops, there was no effect of planting pattern nor amaranth plant population on amaranth plant height and LAI in both years, except in 2005 when amaranth was intercropped within okra plants, amaranth plants were shorter with 111,100 amaranth plants ha^{-1}. The number of branches was significantly ($P < 0.05$) reduced by intercropping but among the plant populations and planting patterns they were similar.

In the sole plants, the edible leaf and marketable yields were higher with 111,100 amaranth plants ha^{-1} than those of 55, 550 plants ha^{-1} in both years (Table 4). Intercropping reduced the edible leaf and marketable yields in both years. Among the intercrops in 2004 and 2005, edible leaf yield was higher when amaranth was intercropped between than within okra plants but there was no effect of amaranth plant population. In within or between okra planting patterns, marketable yield was always higher with amaranth at 111, 100 than at 55, 550 plants ha^{-1} in both years, except that in 2005, the yield was higher with 55, 500 than with 111, 100 amaranths plans ha^{-1}.

Productivity of the systems

There were yield disadvantages of growing okra and Amaranth in mixture as depicted by the LER of 0.63-0.64 (2004) and 0.59 – 0.98 (2005), especially when okra was intercropped with higher amaranth population (Table 5). In each year, okra had higher partial LER than amaranth in all the cropping systems.

Table 4: Edible leaf and marketable yields of amaranth as influenced by amaranth planting density and planting pattern in okra/amaranth intercropping system in 2004 and 2005 wet seasons.

Cropping systems	Edible leaf yield (kg ha^{-1}) 2004	2005	Marketable yield (kg ha^{-1}) 2004	2005
Sole amaranth 55,550 plants ha^{-1}	1999.00	1895.20	3250.67	3180.24
Sole amaranth 111,100 plants ha^{-1}	2593.00	2431.01	4117.33	4105.28
Okra b/w 55,550 amaranth plants ha^{-1}	322.33	350.21	637.61	699.62
Okra b/w 111,100 amaranth plants ha^{-1}	367.33	358.10	905.81	780.00
Okra within 55,550 amaranth plants ha^{-1}	215.67	206.24	390.08	731.46
Okra within 111,100 amaranth plants ha^{-1}	257.67	249.76	576.43	697.90
$LSD_{0.05}$	153.624	180.645	102.30	65.213

Table 5: Land equivalent ratio in okra/amaranth intercropping system in 2004 and 2005 cropping seasons.

Cropping system	Land equivalent ratio 2004 Partial Okra	Amaranth	Total	2005 Partial Okra	Amaranth	Total
Okra b/w 55,550 amaranth plants ha^{-1}	0.91	0.17	1.08	0.84	0.22	1.06
Okra b/w 111,100 amaranth plants ha^{-1}	0.41	0.22	0.63	0.43	0.19	0.62
Okra within 55,550 amaranth plants ha^{-1}	0.88	0.12	1.00	0.75	0.23	0.98
Okra within 111,100 0amaranth plants ha^{-1}	0.47	0.14	0.64	0.42	0.17	0.59

DISCUSSION

Okra and amaranth growth and yield were reduced by intercropping probably because of competition of the two crops in mixture for growth resources. Muoneke and Asiegbu (1997) and Manga *et. al.,* (2003) had reported reduction in growth and yield of some component crops in mixtures. Growth and yield reductions in amaranth were higher than those of okra probably because okra was sown about three weeks before amaranth. The earlier sown okra was taller than *Amaranthus* plants and therefore had their leaves higher up in the canopy than the amaranth plants. Obasi (1989) and Orkwor *et. al.,* (1991) observed that the most important feature of plants that determine their competitive ability for light is height. They concluded that a successful competitor for light is the component that has its foliage at a higher canopy layer. Palaniappan (1985) reported that in an intercropping situation, the taller component crop intercepted the major share of light such that the growth rates of the two crops would be proportional to the quantity of the photosynthetic active radiation they intercepted. In this presented study, okra was taller than amaranth because of its earlier presence and therefore shaded amaranth, especially when amaranth was grown within okra rows. The suppressant effect of okra on amaranth was evident in its higher partial LER than amaranth as shown in Table 5 inspite of the fact that amaranth is a C_4 plant which is supposed to exhibit dominance over okra – a C_3 plant (Hall *et. al.*, 1974).

Irrespective of amaranth planting density, yield and yield components of the two crops were usually lower with within row planting pattern probably because of higher competition among the components in intimate mixtures. When components are grown together within rows, severe mingling of their roots and quest for below ground resources would be high. The yield of each component crop was lower at higher amaranth plant population because of severe competition when the number of plants demanding the scarce resources was high.

Assessing the productivity of the intercropping system using LER indicated yield disadvantages, especially when higher amaranth planting density was involved (yield disadvantage of 37-41% in both years). The implication of this yield disadvantage is that it is better to grow the two crops separately. However, if they must be grown together, the mixture would be okra between 55,500 amaranth plants ha^{-1} with total LERs of 1.08 (2004) and 1.06 (2005), depicting yield advantages of 8 and 6% (Table 5). Uzo (1983) had discouraged intercropping okra of some vegetables.

CONCLUSION

The results of this study showed that it is better to grow okra and vegetable amaranth separately, especially at higher amaranth planting density because there was yield disadvantage when they were grown in mixtures.

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