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Effect of sole and mixed cropping on growth and yield performance of *Amaranthus hybridus*

OKUNLOLA A. IBIRONKE
Department of Crop, Soil and Pest Management, The Federal University of Technology, P.M.B 704, Akure Ondo State, Nigeria.
Author for correspondence e-mail: aiokunlola@yahoo.co.uk
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ABSTRACT
Objective: To evaluate the growth and yield performance of Amaranthus *hybridus* under sole and mixed cropping systems.
Methodology and results: Field experiments were conducted at the teaching and research farm of the Federal University of Technology, Akure during the rainy seasons of 2005 and 2006. The treatments randomized in complete block design and replicated three times were (1) sole *Amaranthus hybridus* (Ama), (2) *Amaranthus hybridus* and *C. argentea* mixture (Ama + Celo); (3) *A. hybridus* and *C. olitorius* mixture (Ama + Cor); (4) *A. hybridus, C. argentea* and *C. olitorius* mixture (Ama + Celo + Cor). The parameters assessed were: plant height, number of leaves/plant, number of branches/plant, stem girth, fresh weights of leaf, shoot, root, leaf area and total biomass. Results showed gradual increase in all the growth parameters measured in the two seasons from 1 to 7 weeks after planting (WAP). Plant heights were highest in sole *A.hybidus* at 5 – 7 WAP in both seasons. Amongst the mixtures *A. hybridus* in mixture with *C. argentea* (Ama + Cel) had significantly higher values for number of leaves and number of branches at 5 – 6 WAP in both seasons. The number of branches and leaves increased from 4 – 7 WAP. Result obtained for both seasons revealed that sole *A. hybridus* had higher edible yield compared to the mix-crops. The study showed that sole-cropped *A. hybridus* had comparable growth and yield parameters with their mixed-cropped counterparts. Therefore planting A. hybridus in mixtures would be advantageous to farmers compared to planting sole.
Key words: *Amaranthus hybridus,* sole cropping*,* mixed cropping*,* leafy vegetables

INTRODUCTION
Vegetables are abundantly grown in Nigeria for their edible fruits (fruit vegetables) leave (leafy vegetables (Oke, 1968; Olasantan, 1989). The term vegetable is frequently used to refer to leafy plants whose succulent stem portions, petioles and leaves are mainly cooked and eaten in soups (Olasantan, 1992). Besides their aesthetic value in food presentation, vegetables enhance the nutritional quality of diets in terms of vitamins and minerals such as carotene (provitamin A), ascorbic acid, riboflavin, iron, iodine and calcium (Shiundu, 2002).
In the traditional agricultural systems of the humid tropics, vegetables are generally cultivated as ‘minor crops’ in mixtures with staple food crops, such as cereals, grain legumes and tubers (Olasantan, 1992). Although some farmers prefer to grow vegetables as sole crops, it is common to find mixtures of different vegetable species on the same piece of land (Uvah, 1992). However, in mixed cropping studies, less research attention

has been paid to vegetables than to field crops. Thus, there is a gap in knowledge and studies are required on the growth and yield of vegetables under mixed cropping conditions. The aim of this study, therefore, was to evaluate the growth and yield performance of *Amaranthus hybridus* (African spinach) under sole, and mixed cropping with *Celosia argentea* (Cock's comb) and *Corchorus olitorius* (Bush okra).

MATERIALS AND METHODS.

Study site: Two field experiments were conducted at the Teaching and Research Farm of the Federal University of Technology, Akure (327 m above sea level; 7^0 16'N, 5^0 12' E) in the rainforest zone of Southwestern Nigeria. Soils at the site are formed over medium-grained granitic gneiss parent material and basement complex parent rock. The soil profile examination by Ewulo et al., (2002) reveal pronounced gravel layer between 20-40 cm depth that satisfy criteria for argillic horizon designation (Soil survey staff, 1998). The area is subjected to marked wet and dry season with a bimodal rainfall pattern. The two rainfall peak makes two growing season possible. There is heavy rainfall in May-June-July, which is interrupted by a dry period of about two weeks in August; this is followed by another period of heavy rainfall from September to October. Dry season length is between 120 -130 days, its finishing date is (at 0.5 probability) the end of Annual rainfall is between 2.0 to 2.5 m; annual temperature range is about 12oC, relative humidity is never below 70% at 9.a.m.

Experimental layout: The first experiment was conducted during the rainy seasons (May – July) of 2005 and repeated in 2006. The site was manually cleared and the debris packed along the borders to ensure a clean seed-bed for sowing the crops. The land area used for the experiment was 10m x 10m. The experiment was laid out into three blocks of 2m length each, with a space of 1m between the blocks and width 20 cm. Each block contained four plots each measuring 2m x 2m with 0.5m spacing between plots in each block. The treatments were arranged in a randomized complete block design and replicated three times. The seeds of the selected vegetable crops, namely: *Amaranthus hybridus*, *Celosia argentea* and *Corchorus olitorious* were obtained from the Ondo State Agricultural Development Programme (ODSADEP).

Beds were made manually with hoe and the seeds of each vegetable were sown by drilling on rows 30 cm apart and later thinned to 20 stands per row at an average spacing of 10 cm within row (60 stands/m^2) at two weeks after planting (WAP). The seeds of the selected vegetable were randomly assigned to plots with the following treatments: (1) *A. hybridus (*sole cropped); (2) *A. hybridus* and *C. argentea;* (3) *A. hybridus* and *C. olitorius;* (4) *A. hybridus, C. argentea,* and *C. olitorius* (mixed cropped). Weeds were manually removed from the plots at two and five weeks after planting (WAP). Standard management practices were employed for the duration of the growing season.

Data collection and analysis: Ten plants per plot of the selected vegetable *A. hybridus* were tagged and used for data collection on weekly basis for seven weeks. Plant height was measured from the ground level to the raised leaf-tip with meter rule, total number of leaves and branches were counted per plant, and stem girth measured using venier calipers. At seven week after planting, the sampled plants in each plot were harvested and taken to the laboratory. The root of the plants were gently washed in water to remove soil particles, fresh weight of leaves, shoot, root and total biomass were determined on a top-loading balance. An automatic leaf area meter (model AAM-5 Tokyo Hayashi Denkko Co., Ltd) was used to determine the leaf area. Data were subjected to analysis of variance and means separated using Duncan's Multiple Range Test (DMR).

RESULTS

Results (tables 1 and 2) showed gradual increase in all the growth parameters measured in the two seasons from 1 to 7 weeks after planting (WAP). Although there were marked variations in the data obtained for the two seasons, they followed the same pattern. Values obtained in 2005 were generally higher than those obtained in 2006.

Plant height: Plant heights were highest in sole *A. hybidus* at 5 – 7 WAP in both seasons. Amongst the mixtures *A. hybridus* in mixture with *C. argentea* (Ama + Cel) had significantly higher values for plant height at 5 – 6 WAP in both seasons; however at 7WAP (2006) it had comparable values when planted in mixtures with *C. olitorius* and *C. argentea* (Ama + Cor + Cel). Plant height increased rapidly from 4 – 7WAP in both seasons as shown in Tables 1 and 2.

Stem girth: Stem girth of *A. hybridus* did not vary significantly in all the treatment groups on a weekly basis from 1 – 3 WAP in both seasons. In 2006 (table 2), significant variations were observed between treatments from 4 – 7 WAP. Highest values were obtained for sole cropped A. *hybridus* in 2006 while plants in the Ama + Cor + Cel group had the highest values at 4 – 7 WAP (4.91 – 6.17 mm). Although the variation observed in 2005 were not significant, plants in Ama + Cel treatment had larger stem girth at 5 – 6 WAP (4.7 and 4. 97mm, respectively) while *A. hybridus* planted with *C. olitorius* (Ama + Cor) had higher value (5.32mm) at 7 WAP. Rapid increases were observed in the stem girth for both seasons from 4 – 7 WAP.

Branches and leaves: In 2005, sole cropped. *A. hybridus* had significantly higher number of branches and leaves at 5 – 7 WAP (7.22 – 11.51 and 41.74 - 68.53, respectively). Plants in the Ama + Cel plots had the highest values among the mixtures with values ranging between 6.24 - 7. 73 and 34.42 - – 42.78 for number of leaves and number of branches, respectively. At 7 WAP, sole cropped *A. hybridus* had significantly higher values of 10.90 branches and 58.26 leaves, respectively (Table 2).

Results (tables 3 and 4) showed that yield parameters were significantly higher in sole cropped *A. hybridus* in both seasons. In both seasons, yield parameter decreased with increasing level of mixing the crops; hence Ama + Cor + Cel group had significantly lower ($P < 0.05$) values in both seasons. The highest impact of mixed cropping in the first season was observed in the Ama + Cor + Cel group with 69, 50, 64 and 67% decreases in shoot weight, root weight, marketable yield and total biomass respectively relative to the sole-cropped *A. hybridus* (Tables 3 & 4). The highest percent decrease in edible yield and leaf area were in 2005 (39 and 44%, respectively).

DISCUSSION

The results of this study revealed that mixed cropping did not enhance the growth of the selected vegetables at 1 – 3 WAP as evidenced by the general absence of significant difference in the height, stem girth, number of stem branches/plant and number of leaves/plant, in sole crop and mixed-crop. This suggests that competition between the mixed-crop vegetables had not vigorously commenced at 1-3 WAP. In addition the component plants in the mixed-crop vegetables were extracting the available nutrient resources from the soil. These results support the observations of Ogoke and Ayodele (1997) who stated that competitive interference of *A. hybridus* and *C. argentea* did not set in at the early vegetative stage.

However, the fact that significant differences were observed in height of *A. hybridus* in *A. hybridus* + *C. argentea* mix-crop at 3 WAP, and stem girth of sole and mix-crop *A. hybridus* at 1 WAP and 3 WAP showed that individual plants compete strongly for the supplies of plant growth factors (light, water and nutrients) (Trelibath, 1974; Palaniappan, 1985). *A. hybridus* was more competitive when planted in mixture with *C. argentea* than *C. olitorius* suggesting there are differences between the components in the way they exploit the site's growth factors (May, 1973; Ikeorgu, 1990).

The increase in the height of sole *A. hybridus* four to seven WAP could be related to light intercepted which is more in the sole crop compared to the mixed crop arrangement. More light interception increases growth because the rate of photosynthesis increases with increasing irradiance levels (Adebayo & Akoun, 2002). Tall vegetation often greatly alters the micro environmental conditions below it.

In the mixtures, stem girth, number of stem branches/plant and number of leaves/plant were higher in the *Amaranthus* + *Celosia* mixture at 5 – 7 WAP for both seasons. This suggests that *A. hybridus* had a stronger competitive ability in the Ama + Cel mixtures compared to Ama + Cor or Ama + Cor + Cel mixtures. In the Ama + Cel mixture the roots of *A. hybridus* were able to occupy a different layer of the soil and hence utilize available space for growth as well as the nutrients available (Aluko, 1989). The nutrient status of soil has been reported to be essential in sustaining the physiological processes controlling growth (Aluko & Onoja, 1990).

Table 1: Growth parameters of *Amaranthus hybridus* under sole and mixed cropping in 2005 season.

		Growth Parameters			
Crop mixtures	Weeks after planting (WAP)	Plant Height (cm)	Stem girth (mm)	No. of BranchesPlant^{-1}	No. of Leaves Plant^{-1}
Sole *A. hybridus*	1	4.76c	1.78a	0.00	6.26a
A.hybridus + *C.olitorius*	1	4.23b	1.54a	0.00	5.88a
A.hybridus + *C. argentea*	1	3.45a	1.42a	0.00	5.23a
Ama + Cor + Cel	1	4.12b	1.57a	0.00	5.40a
Sole Amaranthus	2	11.16a	2.39a	0.00	11.85a
A.hybridus + *C.olitorius*	2	10.00a	2.24a	0.00	12.17a
A.hybridus + *C. argentea*	2	10.09a	2.35a	0.00	11.40a
Ama + Cor + Cel	2	10.18a	2.48a	0.00	11.30a
Sole Amaranthus	3	18.63b	2.73a	0.00	18.16a
A.hybridus + *C.olitorius*	3	17.70ab	2.42a	0.00	17.60a
A.hybridus + *C. argentea*	3	19.91c	2.88a	0.00	19.12a
Ama + Cor + Cel	3	17.39a	2.77a	0.00	19.16a
Sole Amaranthus	4	28.57b	4.53a	2.96a	24.43a
A.hybridus + *C.olitorius*	4	24.93a	4.39a	4.06c	26.12a
A.hybridus + *C. argentea*	4	23.89a	4.58a	3.57b	24.58a
Ama + Cor + Cel	4	23.37a	4.51a	2.97a	23.39a
Sole Amaranthus	5	43.70c	4.64a	7.22c	41.74c
A.hybridus + *C.olitorius*	5	32.43a	4.56a	6.12b	31.82a
A.hybridus + *C. argentea*	5	35.85b	4.70a	6.24b	34.42b
Ama + Cor + Cel	5	32.99a	4.48a	5.34a	31.35a
Sole Amaranthus	6	44.65c	4.98a	9.39c	48.88c
A.hybridus + *C.olitorius*	6	34.80a	5.07a	7.77a	41.93b
A.hybridus + *C. argentea*	6	37.98b	4.97a	8.30b	42.64b
Ama + Cor + Cel	6	33.71a	4.87a	7.20a	34.49a
Sole Amaranthus	7	58.63c	5.21a	11.51c	68.53c
A.hybridus + *C.olitorius*	7	42.52a	5.32a	7.30ab	42.43b
A.hybridus + *C. argentea*	7	54.54b	5.18a	7.73b	42.78b
Ama + Cor + Cel	7	42.14a	4.99a	6.58a	35.48a

Values followed by the same letter within a column are not significantly different (P<0.05)

Table 2: Growth parameters of *Amaranthus hybridus* under sole and mixed cropping in 2006 season.

		Growth Parameters			
Crop mixtures	**Weeks after planting (WAP)**	**Plant Height (cm)**	**Stem girth (mm)**	**No. of Branches Plant^{-1}**	**No. of Leaves Plant^{-1}**
Sole Amaranthus	1	8.27	2.05	0.00	20.07b
A.hybridus + *C.olitorius*	1	5.66a	1.84a	0.00	20.32b
A.hybridus + *C. argentea*	1	7.49b	1.99a	0.00	20.05b
Ama + Cor + Cel	1	7.10b	1.91a	0.00	17.20a
Sole Amaranthus	2	9.65cd	2.59a	0.22b	27.31c
A.hybridus + *C.olitorius*	2	8.90bc	2.42a	0.02a	25.30b
A.hybridus + *C. argentea*	2	10.67d	2.40a	0.54c	27.05c
Ama + Cor + Cel	2	7.47a	2.24a	0.17b	24.01a
Sole Amaranthus	3	15.25c	3.11a	0.78b	33.31b
A.hybridus + *C.olitorius*	3	10.41a	2.84a	0.30a	30.30a
A.hybridus + *C. argentea*	3	17.98d	2.93a	2.20c	36.8c
Ama + Cor + Cel	3	12.78b	2.84a	0.57ab	31.7a
Sole Amaranthus	4	26.94b	3.89a	2.62b	40.86bc
A.hybridus + *C.olitorius*	4	20.39a	3.21a	1.63a	36.39a
A.hybridus + *C. argentea*	4	24.92b	5.28b	3.62c	42.28c
Ama+ Cel + Cor	4	24.92b	3.21a	1.63a	23.48
Sole Amaranthus	5	35.10b	4.48b	5.48b	44.48b
A.hybridus + *C.olitorius*	5	26.39a	3.93a	3.88a	40.50a
A.hybridus + *C. argentea*	5	38.81c	3.59a	6.15c	48.34c
Ama + Cor + Cel	5	34.53b	4.91b	4.28a	42.0ab
Sole Amaranthus	6	39.72c	5.49b	7.17b	49.92c
A.hybridus + *C.olitorius*	6	29.79a	4.26a	4.45a	43.25a
A.hybridus + *C. argentea*	6	43.99d	4.37a	7.55b	52.53d
Ama + Cor + Cel	6	36.77b	5.65b	4.97a	46.53b
Sole Amaranthus	7	56.07c	6.34b	10.90d	58.26c
A.hybridus + *C.olitorius*	7	35.52a	5.05a	5.48b	47.73a
A.hybridus + *C. argentea*	7	41.49b	5.15a	7.65c	56.10c
Ama + Cor + Cel	7	42.14b	6.17b	4.88a	51.10b

Values followed by the same letter within a column are not significantly different ($P<0.05$)

Ama = *A. hybridus* Cor = *C. olitorius* Cel = *C. argentea*

Table 3: Yield of *Amaranthus hybridus* under sole and mixed cropping at 7 WAP (2005)

Crop mixtures	Leaf Area (cm2)	Edible (glm2)	Shoot weight (g/plant)	Root weight g/plant-1)	Marketable (Yield (g/m2)	Total biomass (g/m2)
Sole *A. hybridus*	75.60c	18.83b	54.43c	8.20c	49.34d	66.63d
A.hybridus + *C.olitorius*	53.90b	13.76a	41.34d	8.20c	40.24b	47.56b
A.hybridus + *C. argentea*	3.40b	13.58a	49.83b	6.73b	42.45c	56.56c
Ama + Cor + Cel	42.50a	11.48a	40.49a	4.95a	38.26a	45.44a

Values followed by the same letter within a column are not significantly different (P<0.05)

Table 4: Yield of *A. hybridus* under Sole and mixed cropping at 7 WAP 2006

Crop mixtures	Leaf Area (cm^2)	Edible (glm^2)	Shoot weight (g/plant)	Root weight ($g/plant^{-1}$)	Marketable Yield (g/m^2)	Total biomass (g/m^2)
Sole *A. hybridus*	43.37b	26.74c	67.03c	9.52c	65.51c	43.37b
A.hybridus + *C.olitorius*	47.88c	23.16b	19.06a	7.34b	26.40a	47.88c
A.hybridus + *C. argentea*	40.18a	22.35b	40.18b	8.48b	48.66b	40.18a
Ama + Cor + Cel	40.01a	20.33a	20.17a	4.79a	25.50a	40.01a

Values followed by the same letter within a column are not significantly different (P<0.05)
Ama = *A. hybridus* Cor = *C. olitorius* Cel = *C. argentea*

The number of leaves/plant of *A.hybridus* was higher in the sole crop than the mixtures, possibly due to reduced competition for sunlight and soil nutrients in the sole crop than in the mixtures. The work of Aluko and Onoja, 1990 further suggests that the growth of leaves is influenced more by nitrogen and crop growth rate is dependent on the area of the leaf surface. The reduced growth of *A. hybridus* in the mixtures might be due to mutual leaf shading effect and competitive nature of the other vegetables.

In addition, plants with more erect leaves are considered more efficient than those with the leaves positioned horizontally because they are able to trap photosynthetically active radiation and have higher photosynthetic activity (Evans, 1993). *A. hybridus* is a C_4 plant and hence it's a more efficient user of light for rapid vegetative growth (NIHORT, 1985). The enhanced yield of sole *A. hybridus* compared to mixed crop confirms the known positive relationship between the leaf surface and its efficiency as a producer of dry matter. Under sole cropping the plants were less subject to shading effect, and are able to intercept the maximum amount of radiation in the early stages of growth and throughout the season, which resulted in greater photosynthate production, and hence higher yield (Ibrahim, 2002). Also, crops differ in their capture and use of growth resources such that when they are grown in combination, they either complement each other or compete for the available resources (Wiley, 1979).

CONCLUSION

This work has shown that though sole-cropped *A. hybridus* had higher growth and yield for the parameters considered the results were however comparable with their mixed-cropped counterparts. Hence planting *A. hybridus* in mixtures is advantageous compared to planting sole.

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