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Growth and Yield Performance of *Amaranthus cruentus* Influenced by Planting Density and Poultry Manure Application

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Abstract

Field trials were conducted in 2007 and 2008 to determine the influence of planting density and poultry manure application on the growth and yield of *Amaranthus cruentus* (Linnaeus). This study was conducted at the teaching and research farms of Benson Idahosa University, Benin City using two planting densities (111111 and 62500 plants per hectare) and three levels of poultry manure (0.0, 6.0 and 12.0 t ha^{-1}) in a 2 x 3 factorial arrangement fitted into randomized complete block design with three replicates. Results showed that planting density and poultry manure significantly (P = 0.05) affected the number of leaves, leaf area index, total dry matter and the crop growth rate positively in favour of increasing planting density and poultry manure application rate leading to higher herbage yield. The results showed that the combination of 62500 plants per hectare and application of poultry manure of 12 t ha^{-1} provided the highest yield (15.74 t ha^{-1}).

Keywords: Crop growth rate, planting density, poultry manure and yield

Introduction

Amaranthus cruentus (Linnaeus) is a popular leafy vegetable cultivated in Nigeria and other West African countries although it originated from South America (Saunder and Beciker, 1984). Apart from its uses as a vegetable, it has also been used as an effective alternative to drug therapy in people with hypertension and cardiovascular disease (CVD) (Martiorosyan and Miroshnichen, 2007). The demand for this crop as vegetable has increased, especially in the urban centres where people are not involved in primary production (Schippers, 2000). This has made the vegetable to become an important commodity in our market and production an important economic activity for the rural women.

The yield per hectare of this crop is low (7.60 t ha^{-1}) when compared to that of United States (77.27 t ha^{-1}) and world average (14.27 t ha^{-1}) (FAO, 2007). For commercial production, optimum performance of the crop must be desirable through changes in cultural practices (sterrett and Savage, 1989). Such cultural practices include higher planting density and application of organic manures and fertilizer for improving growth and yield of crop. Fertilizer application is the quickest and easiest ways of increasing crop productivity. Experimental studies have revealed that the increased productivity associated with fertilizer application is with a lot of negative effects which include pollution of ground water after harvest and does not improved soil tilth (Gordon *et al*., 1993), non-readily available and economically not feasible (Lar and Kang, 1982). Many crop species respond well to the application of organic manure and it can sustain yield under continuous cropping through the high potential of gradual nutrient release to the soil that can help to improve the fertility of a degraded soil (Egharevba and Ogbe (2002); Ibeawuchi *et al*., 2006; Mbonu and Afrifalo, 2006).

This study was conducted to evaluate the effects of planting density and poultry manure application on growth and yield of amaranth in a bid to identify an optimum planting and poultry manure regime that would optimize yield and productivity.

Materials and methods

The study was conducted at the Teaching and Research Farms, Benson Idahosa University, Benin City between October, 2007 and March, 2008. Benin City is located on latitude $5^0 45'$ N and longitude $5^0 04'$ E, characterized by a tropical climate, which lie within the humid region. The area has a bimodal rainfall with mean annual rainfall of 1761.90 mm and a daily temperature of 26.5^0 C.

The soil used for the trial has been cultivated in previous years; there was no record of fertilizer usage. The soil was well drained, of gentle slope. The composite soil sample (0-30 cm depth) taken from the site, air-dried in laboratory, ground, sieved through a 2 mm sieve and analysed for its routine soil physical and chemical properties using standard laboratory procedures outlined by Mylaravapus and Kennelley (2002). The soil routine analysis showed that it had pH (H_2O) 6.00; organic carbon (g kg^{-1}) 9.40; total nitrogen (%) 0.36; available phosphorus (mg kg^{-1}) 9.56; C: N ratio 26:1; exchangeable Mg (cmol kg^{-1}) o.53;

1.20; exchangeable K (cmol kg^{-1}) 1.20; exchangeable Ca (cmol kg^{-1}) 1.02; Clay (g kg^{-1}) 250.00; Silt (g kg^{-1}) 100.00 and Sand (g kg^{-1}) 650.00.

The results of the chemical analysis of cured poultry manure used for the trials showed that it had organic carbon 14.97 %; total nitrogen 1.84 %; total phosphorus 0.53% while the C:N and C:P ratios are 8:1 and 28:1, respectively.

Seeds (variety NH 84/445 from NIHORT) were sowed in seed trays (nursery) filled with top soil bed by broadcasting the seeds. The seedlings remained in the nursery for four weeks with routine management like watering and weeding when necessary, after which they were transplanted to the field. Raised beds were constructed and used in the field measuring 1.2 x 6.0 m per plot. Each plot carried a treatment. The poultry manure used for the trial was cured for two weeks before it was applied to the field. Three rates of poultry manure (0.0, 6.0 and 12.0 t ha^{-1}) were applied and incorporated into the soil in the field a day after seedbed preparation; this was done in the morning and was allowed to decompose and watered regularly before transplanting the seedlings three weeks later at a spacing of 30 x 30 cm and 40 x 40 cm to give planting density of 111111 and 62500 plants per hectare (pph), respectively. Seedlings were supplied to missing stands a week after transplanting (WAT).

Plant growth was monitored in-situ from four randomly sampled plants per plot using conventional growth indices such as number of leaves, plant height, stem girth, leaf area, leaf area index (LAI) at two, four and six WAT. However, stem girth and plant height were taken at two and four WAT only.

Total dry weight was determined by destructive sampling (ISTA, 1993) every two weeks, starting from four WAT. The total dry weight and leaf area were used to estimate growth parameters: crop growth rate (CGR) and LAI, respectively as outlined by Remison (1997). Eight plants selected per plot for the determination of herbage yield at eight WAT.

Analysis of variance was carried out on each of the observations recorded for each year of study, followed by combined analysis over two years. The Least Significant Difference (LSD) test was used for detecting significance differences between means at 5% level of probability.

Results and discussion

Vegetative and growth characters

Stem girth increased significantly with increased rates of poultry manure and planting density at both two WAT (Tab. 1) and four WAT (Tab. 2). The plants at all treatment combinations showed a steady growth in stem girth over sampling periods. The widest girth was recorded at 111111 pph with 121 t ha^{-1} at four WAT in both cropping seasons.

Observations from the trial have shown that plant height decreased with increased plant density at two and four WAP (Tab. 1 and 2). The decrease in plant height resulting from increased planting density was attributed to inter-plant competition for space, light, moisture and nutrients. Plant height increased significantly as poultry manure application increased (Tab. 1 -3). The highest height was observed in plants treated with 12 t poultry manure ha^{-1}. The untreated plants were stunted as they had to depend mainly on the intrinsic soil fertility as exhibited by the soil chemical analysis to be low. This position was earlier reported by Opara (1992), Ehigiator (1998) and Egharevba and Ogbe (2002). The highest height exhibited by plants treated with CPM at the 12 t ha^{-1} might have been due to the presence of the primary nutrients (NPK) plus calcium and magnesium found in organic manure, confirmed by FAO (1989) and chemical analysis of the poultry manure. The height of the plant is an important growth character directly linked with the productive po-

Tab. 1. The influence of planting density and poultry manure on the vegetative characters and growth of *Amaranthus cruentus* at 2 WAT

Planting density	Stem girth (cm)				Plant height (cm)				No. of leaves				Leaf area index			
(PPh)	Poultry manure rate (t ha-1)				Poultry manure rate (t ha^{-1})				Poultry manure rate (t ha^{-1})				Poultry manure rate (t ha^{-1})			
	0	6	12	Mean	0	6	12	Mean	0	6	12	Mean	0	6	12	Mean
62500	1.33	1.58	1.58	1.50	7.82	8.73	9.02	8.52	9.33	10.83	12.07	10.74	1.29	1.56	2.66	1.84
111111	1.22	1.35	1.65	1.41	6.53	6.93	8.17	7.21	8.83	9.00	9.50	9.11	1.34	2.48	2.68	2.16
Mean	1.30	1.47	1.62	1.45	7.63	7.97	7.99	7.87	9.08	9.92	10.78	9.93	1.32	2.02	2.67	2
LSD (0.05) Planting density				ns				1.063				1.23				0.281
LSD (0.05 Poultry manure				ns				ns				0.73				0.344
LSD (0.05) Planting density x Poultry manure				ns				ns				ns				ns

ns - not significant at 5% level of probability.

Tab. 2. The influence of planting density and poultry manure on the vegetative character and growth of *Amaranthus cruentus* at 4 WAT

Planting density	Stem girth (cm)				Plant height (cm)				Nos of leaves				Leaf area index (m)				Total dry weight (g)			
(PPh)	Poultry manure rate (t ha^{-1})				Poultry manure rate (t ha^{-1})				Poultry manure rate (t ha^{-1})				Poultry manure rate (t ha^{-1})				Poultry manure rate (t ha^{-1})			
	0	6	12	Mean	0	6	12	Mean	0	6	12	Mean	0	6	12	Mean	0	6	12	Mean
62500	3	3.13	3.17	3.10	25.30	28.90	34.40	29.60	39.80	53.70	54.70	49.40	4.51	5.51	6.94	5.66	0.63	0.67	0.97	0.76
111111	2.93	3.63	3.8	3.46	28.70	40.60	41.00	36.80	42.50	66.20	66.30	58.30	4.92	8.18	8.71	7.27	0.89	1.12	1.13	1.05
Mean	2.96	3.38	3.49	3.28	31.60	33.20	34.70	33.20	41.20	59.90	60.50	53.90	4.72	6.85	7.83	6.46	0.76	0.89	1.05	0.90
LSD (0.05) Planting density				0.520				5.450				11.200				1.530				0.210
LSD (0.05) Poultry manure				0.630				6.680				13.800				1.880				0.250
LSD (0.05) Planting density x Poultry manure				0.890				9.440				19.500				2.650				0.360

ns - not significant at 5% level of probability.

Tab. 3. The influence of planting density and poultry manure on the vegetative character and growth of *Amaranthus cruentus* at 6 WAT

Planting density	No. of leaves				Leaf area index (m)				Crop growth rate (g m^{-2} wk^{-1})			
(PPh)	Poultry manure rate (t ha^{-1})				Poultry manure rate (t ha^{-1})				Poultry manure rate (t ha^{-1})			
	0	6	12	Mean	0	6	10	Mean	0	6	10	Mean
62500	85.70	96.70	106.80	96.40	6.1	6.95	8.81	7.3	0.52	0.72	0.85	0.69
111111	100.70	101.30	104.70	102.20	7.1	9.29	9.72	8.71	0.57	0.98	1.25	0.93
Mean	93.20	99.00	105.80	99.30	6.6	8.12	9.27	8.00	0.56	0.85	1.05	0.81
LSD (0.05) Planting density				30.790				1.060				0.260
LSD (0.05) Poultry manure				37.710				1.290				0.320
LSD (0.05) Planting density x Poultry manure				53.340				1.820				0.450

Tab. 4. The influence of planting density and poultry manure on the growth of *Amaranthus cruentus* at 8 WAT

Planting density	Crop growth rate (g m^{-2} wk^{-1})				Yield (t ha^{-1})			
(pph)	Poultry manure rate (t ha^{-1})				Poultry manure rate (t ha^{-1})			
	0	6	10	Mean	0	6	10	Mean
62500	0.83	1.23	1.93	1.33	9.70	10.00	15.70	11.82
111111	0.43	1.88	2.13	2.15	11.00	13.30	14.20	12.62
Mean	0.63	1.58	2.03	1.74	10.00	11.70	15.00	12.32
LSD (0.05) Planting density				0.970				43.430
LSD (0.05) Poultry manure				1.190				35.460
LSD (0.05) Planting density x Poultry manure				1.680				61.420

tential of plants. An optimum plant height is claimed to be positively correlated with productivity of plants (Saeed *et al*., 2007).

The number of leaves increased significantly with increased rates of poultry manure from two to six WAT (Tab. 1-3) and the number of leaves increased as the planting density decreased at two WAT (Tab. 1), but increased significantly with poultry manure at four and six WAT (Tab. 1 and 3). Foliage production also showed a steady increase over sampling period for all the treatment combinations with the rate of leaf production being the highest at six WAT (Tab. 3). The best results were obtained from a combination of 111111 pph and 12 t poultry manure ha^{-1} at WAT in both cropping seasons. Changes in the number of leaves are bound to affect the overall performance of amaranth as the leaves serve as photosynthetic organ of the plant (Ayodele, 1983).

LAI and number of leaves followed the same pattern as LAI and number of leaves were directly related ($r = 0.64$, $P > 0.05$). The LAI increased significantly as the planting density and poultry manure rate increased from two to six WAT (Tab. 1-3). A combination of 111111 pph and 12 t ha^{-1} had the greatest LAI throughout the sampling periods. The positive effect of poultry manure increasing LAI of amaranth was earlier reported by Egharevba and Ogbe (2002) but it was more pronounced in this trial due additional influence of planting density.

The CGR increased significantly as the planting density and poultry manure rate increased at four to eight WAT (Tab. 3 and 4). The increased CGR was due to enhanced LAI. LAI of a plant is an indication of its photosynthetic assimilation and translocation. This will certainly be reflected in plant growth and vigour.

Yield (Herbage yield)

The yield responds positively to planting density and poultry manure application as they both increased yield (Tab. 4). The effect of increased planting density was observed to be more pronounced with increased poultry manure rate. Increased planting density alone without poultry manure application depressed yield as observed through wilted and yellowish leaves. Fresh yield were least with plants without the application of poultry manure in both cropping seasons. A plant population of 62500 pph and poultry manure rate of 12 t ha^{-1} had the highest yield in both cropping seasons (Tab. 4). Amaranth yield was least without application of poultry manure. This confirmed the findings of Adediran and Banjoko (2002), who reported that the application of manure for enhancement of yield of crop.

Conclusions

This investigation revealed that a combination of planting and poultry manure application at a plant population of 62500 and 12 t ha^{-1} had positive effects on all growth parameters and so should be recommended to farmers and/or leafy vegetable growers like amaranth because it is easily available, economical and it does not have the tendency of making the soil acidic since it is moderately available and improved the physical properties of the soil.

Due to low nitrogen and phosphorus of the highly weathered soils in the tropics, it is thereby recommended that future study would be the incorporation of NPK fertilizer into poultry manure in order to increase the available nitrogen, phosphorus and potassium in the manure. More researches should be carried in this direction by increasing the planting density and poultry manure application using the same crop and other leafy and fruit vegetables like *Telfaria occidentalis*, *Celosia argentea*, *Corchorus olitorius*, *Abelmoschus esculentus*, etc.

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