INFLUENCE OF POULTRY MANURE AND IRRIGATION FREQUENCY ON GROWTH AND YIELD OF GRAIN AMARANTH (*Amaranthus cruentus L.*) IN ASABA AREA, SOUTHERN NIGERIA.

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Abstract
The pot experiment was conducted on the growth, yield and irrigation water use efficiency of Amaranth *(Amaranthus cruentus)* in response to irrigation frequency and poultry manure at the Teaching and Research Farm of the Faculty of Agriculture, Delta State University, Asaba Campus between mid-November 2015 to February 2016. Poultry manure was applied at the rate of 3.5, 7.0 and 10.5 t ha^{-1} including the control, without nutrient application. The irrigation frequency consists of three artificial irrigation regimes which involved watering once, twice and thrice per week. The experiment was a 4x3 factorial laid in a randomized complete block design (RCBD) with three replicates. The parameters measured were plant height, number of leaves, total leaf area, fresh weight, dry weights, length of panicle, number of panicles, panicle dry weight, grain yield and irrigation water use efficiency. Increased rate of poultry manure significantly increased plant height, leaf area dry matter yield and grain yield. Highest plant height (216.05cm), leaf area (13457.9 cm^2), dry weight of panicle (18.4g) and grain yield (5.83g) were obtained at 10.5kg ha^{-1}. On the average twice irrigation indicated the highest vegetative parameters, components of yield and grain yield. Irrigation water use efficiency reduced increase in irrigation frequency.
Keywords: grain amaranth, irrigation, irrigation, water use efficiency, poultry manure

Introduction

In most Sub-Sahara Africa countries, such as Nigeria, the dominant staple foods in their daily diet are either starchy or vegetable based. Vegetables are readily available during both rainy and dry seasons. Amaranth is an annual dicotyledonous herbaceous plant with C_4-photosynthesis pathway. Its anatomical attributes allows for efficient utilization of carbon dioxide under a wide range of environmental conditions such as moisture stress, temperature (25^{0}C to 40^{0}C) and high light intensity (Silva *et al.*, 2010).

Amaranthus cruentus belongs to the family Amaranthaceae, and is one of the seed-producing species. *A. cruentus* is popularly cultivated vegetable called green vegetable or African spinach. Its cultivation cuts across all parts of Nigeria in the urban and peri-urban areas, from the south to the North and is used as both leaf and grain vegetable, hence the need for more attention to increase its productivity. The leaves and stem are high in protein (15 to 24 %), minerals and vitamins. The grain also contains 12 to 17% protein. It's also high in amino acid (lysine) and rich in iron, calcium, potassium and vitamins A and C (Anon, 2010). Besides its nutritional importance, cultivation of amaranth has been an income generating activity for smallholder farmers hence contributing to livelihood of the low income population.

Despites its societal importance, cultivation of *A. cruentus* has been limited by poor soil nutrients and availability of agricultural water especially in the dry season. Though cultivated in the urban and peri-urban areas, most of the vegetables consumed usually come from hinterlands, were water scarcity is a regular phenomenon.

Most soils in Sub-Sahara Africa are inherently deficient in organic carbon, acidic and relatively sandy. That explains the current advocacy for use of organic manures in preference to inorganic fertilizers for cultivation of amaranth vegetable (Adeoye *et al.* 2005; Adewole and Dedeke, 2012). One of such soil nutrients for vegetable cultivation is poultry manure. Poultry manure is high in organic matter and contains available nutrients for crop growth. Fertilizers of organic origin improves soil texture and structure, as well as forming complexes with soil colloids or minerals (especially, humic substances) and will generate long term positive effects on soil fertility (Ghabbour and Davis, 2001).

Grain amaranth response to soil nutrient applications has been documented by several researchers. Akinwumi *et al.* (2011) reported significant increase in plant height and stem girth, while a combination of poultry manure and NPK positively improved number of leaves of grain amaranth. Increased plant height, number of leaves, leaf area and number of branches of three species of amaranth has also been reported by Oyedeji *et al.* (2014). Adewole and Dedeke (2012) also observed increase in all growth parameters of *A. cruentus* with increase in poultry manure applications.

The economic and sustainable application of water to achieve maximum crop productivity is termed irrigation. The method to be used depends on local conditions such as soil moisture flow; crop characteristics, topography and aquifer discharge (Adejumobi *et al.* 2015). In the absence of rainfall especially in the dry seasons, poor timing of irrigation can result in crop water deficit leading to water and nutrient deficiency, delayed crop maturity which consequently results in poor crop yield. Moisture shortage at early stage of crop growth results in poor root development, while shortage at later part of crop growth leads to poor quality crop produce even if total yield is not affected (Saleh *et al.* 2007). In a related study, three times application of 1 litre to okra was observed to have recorded highest plant height, number of leaves, stem diameter and pod yield in okra (Adejumobi *et al.* 2015). Saleh *et al.* (2007) recorded that 5 days irrigation frequency conserved 18% and 12% of water at the early stage of tomato development relative to 1 to 3 days frequencies. Even small of irrigation water applied at heading, flowering and milking stages of growth in sunflower can significantly increase seed yield (Unger, 1983; Stone *et al.*, 1996). Shafi *et al.* (2013) observed that sunflower crop which received triple three irrigations at heading stage, heading + flowering stages, and heading + flowering + grain filling stages produced taller plants, bigger heads, maximum 100 seed weight and high seed yield than double and single irrigation treatments. Efficient use of water applied to the crop is also important for nutrient uptake, crop development, biomass and grain yield. Water use efficiency is the physiological output obtained in relation to the known amount of water input to the crop (Singh *et al.* 2012).

The objective of this study was to determine the appropriate rate of poultry manure and irrigation frequency that can maximize crop growth, yield and water use efficiency in *Amaranthus cruentus*.

Materials and Methods

The pot experiment was conducted under an open sided roof structure during the dry season between mid-November 2015 to February 2016 at the Teaching and Research Farm of the Faculty of Agriculture, Delta State University, Asaba Campus. The experimental site is situated between latitude 06^0 14' N and longitude 06^0 49'E in Delta State, Nigeria. The three poultry manure rates evaluated were applications at 3.5, 7.0 and 10.5 t ha^{-1} (corresponding to 45.9g, 30.6g and 15.3g per pot, respectively) in addition to the control (without poultry manure). Three artificial irrigation regimes at the rate of 900 ml per application time were used and involved watering once, twice and thrice per week. The four poultry manure application rates and three irrigation regimes were combined in a 4x3 factorial and arranged in a randomized complete block design (RCBD) with three replicates. Amaranth seeds were obtained from the Agricultural Development (ADP) Office Ibusa, Delta State.

Thirty-six buckets (36) each with a volume of 10 litres were used. The base of each bucket was drilled at eight points to facilitate free drainage of leachates. Each bucket was filled with 9.8kg of sieved 10mm loamy soil and placed on a platform 30cm above ground level. Each bucket was filled with water until saturated. The saturated soil surface was covered with polythene sheets and allowed to stand for four days to attain field capacity. Results of pre-planting soil analysis and poultry manure using methods described by IITA (1979) are presented in Table 1.

Grain amaranth seeds were planted in a nursery and later transplanted to the buckets after two weeks at the rate of one seedling per pot. Poultry manure was applied in a single application three days before transplanting. Growth parameters collected were plant height, number of leaves, and total leaf area at three weeks interval.

The total leaf area per plant was calculated using the equation below:

TLA = nLA

Where n = number of leaves per plant; LA = Leaf lamina area per leaf.

The leaf lamina area (LA) of amaranth was obtained using the linear regression model developed by Kintomo and Ojo (1999).

LA = 0.5049(L x W x 0.4788), Where L and W are length and width of leaf lamina respectively.

In other to obtain the dry weight, three plants were harvested by uprooting at 9 WAT from each plot. Roots of plants were properly washed to remove soil. Whole plants were oven dried at temperature of 72^0C for 48 hours.

Yield and yield components parameters collected were length of panicle, number of panicles, panicle dry weight, 1000 dried seed weight, percent moisture of grain at harvest and grain yield. Irrigation Water Use Efficiency (IWUE) of the crops was estimated using the following formula (Payero et al. 2008; Abubakari *et al.* 2016):

IWUE = DMY/CMW

Where: IWUE = Irrigation water use efficiency (kg/m^3)

DMY= dry mass or wet mass of whole plant (kg)

CMW=cumulative amount of irrigation water applied (m^3).

Data obtained from the study were subjected to analysis of variance (ANOVA), appropriate for factorial arranged in RCBD pattern according to Steel and Torrie (1980). The least significant difference (LSD) 5% level of probability was used for separation of treatment means for significant effects.

Table 1. Properties of the soil and composted poultry manures used during the experiments

Property	Soil	Poultry manure
pH (1:1, soil:water)	5.85	nd
Organic carbon (g kg^{-1})	11.07	nd
Total nitrogen (g kg^{-1})	1.10	0.38
Available phosphorus (g kg^{-1})	4.67	0.56
Exchangeable bases (cmol kg^{-1})		
K	0.38	1.25
Ca	0.54	2.98
Mg	0.73	1.40
Na	0.49	nd
Zn (mg kg^{-1})	nd	0.02
Cation Exchange capacity (cmol kg^{-1})	2.14	nd

nd = not determined

Results and Discussion

Plant height

Results shown in Table 2 indicated that poultry manure and irrigation frequency had significant effect (P<0.05) on plant height. Tallest plants were consistently observed on 10.5 $kgha^{-1}$ with maximum plant height of 216.05cm at 12 weeks after transplanting (WAT), while the control had the opposite effect of producing the shortest plants (151.3cm). The increased plant height with the higher amount of poultry manure may be due to availability of sufficient and balanced nutrients in the manure needed for the growth of the crop. Makinde *et al.* (2010) and Okokoh and Bisong (2011) had earlier obtained similar increase in plant height with increase in application of organomineral fertilizer and poultry manure respectively on *A. cruentus*. Tallest plants were recorded in plants with twice irrigation per week up till 12 WAT while once irrigation per week had the shortest plants. The reduced plant height with once application is an indication of water shortage. Saleh *et al.* (2007) observed that water stressed plants generally exhibit a reduced below and above ground root-shoot system configuration and attributed it more to reduced xylem water potential, since xylem water potential is directly related to soil moisture availability.

Table 2. Influence of rate of poultry manure and irrigation frequency on plant height (cm) of *Amaranthus cruentus*

	Week after transplanting (WAT)			
	3	6	9	12
Poultry manure (t/ha)				
0	24.30c	58.51c	126.62d	151.31d
3.5	30.33b	63.12b	130.90c	170.30c
7.0	41.32a	78.04a	142.61b	199.71b
10.5	45.71a	80.61a	150.90a	216.05a
LSD $_{(0.05)}$	6.23	4.95	3.88	12.45
Irrigation frequency				
Once	30.71c	63.82b	129.30b	158.12c
Twice	41.40a	73.91a	143.83a	200.52a
Thrice	34.82b	72.61a	141.62a	186.50b
LSD $_{(0.05)}$	3.11	4.50	7.83	17.82
PM x R	*	*	**	**

PM- Poultry manure; R - Irrigation frequency
*, ** Significant at 5% and 1% respectively

Number of leaves

The effects of poultry manure and irrigation frequency on the number of leaves of grain amaranth is presented in Table 3. At 3 WAT, poultry manure had no significant effect on number of leaves, but showed significant effect at 6, 9 and 12 WAT. Number of leaves increased to a maximum of 73 leaves at 9 WAT with 10.5 $kgha^{-1}$ and decreased thereafter. On the average, number of leaves decreased by 19.3% between 9 and 12 WAT. In consonance with higher leaf number from increased poultry manure obtained in this study, increase in number of leaves using composted animal manures or organic wastes applied sole or in mixture with inorganic fertilizers were reported to have significantly increased leaf number in *A. cruentus* (Makinde, 2007; Adewole and Dedeke, 2012). Oyedeji *et al*. (2014) also observed more leaves with *A. cruentus* grown with poultry manure than NPK and control. Twice irrigation recorded grain amaranth plants with the highest number of leaves ranging from 19.0 to 63.7, while one time irrigation recorded the least leaf number within the range of 14.2 and 43.7. Yarnia *et al*. (2013) observed reduced number of leaves with low irrigation regimes in amaranth. Moisture availability increase leaf meristem activity and increase of the leaf meristem activity leads to increase in the number of leaves. Conversely, moisture stress reduces leaf number during vegetative stage, hence limiting the emergence of leaves. Moisture availability can also reduce the aging and falling of leaves and consequently increase the leaf number of the plant (Prasad and Staggenborg, 2008; Hlavinka *et al*. 2009). Poultry manure x irrigation frequency interactions were significant for plant height up till 12WAT.

Table 3. Influence of rate of poultry manure and irrigation frequency on number of leaves per plant of *Amaranthus cruentus*

	Week after transplanting (WAT)			
	3	**6**	**9**	**12**
Poultry manure (t/ha)				
0	13.70b	20.06b	38.23d	30.92d
3.5	16.83ab	23.71b	46.52c	38.63c
7.0	18.82a	38.60a	58.70b	49.32b
10.5	18.51a	35.61a	73.33a	56.30a
$LSD_{(0.05)}$	2.56	5.61	4.17	5.08
Irrigation frequency				
Once	14.21b	24.70b	43.72c	34.63c
Twice	19.04a	33.15a	63.63a	51.72a
Thrice	16.92b	30.64a	55.32b	44.82b
$LSD_{(0.05)}$	3.08	4.62	3.89	4.65
PM x R	*	*	*	*

PM- Poultry manure; R - Irrigation frequency
*, ** Significant at 5% and 1% respectively

Total plant leaf area

Both the poultry manure rate and irrigation frequency had significant effect on total leaf area of grain amaranth as presented in Table 4. At 9 WAT, poultry manure increased total plant leaf area by 34.2%, 96.8% and 200.2% at 3.5 kgha^{-1}, 7.0 kgha^{-1} and 10.5 kgha^{-1} respectively when compared to the control without any poultry manure. Poultry manure rate of 10.5kgha^{-1} recorded maximum leaf area (13457.9 cm^2). Earlier research reports also agree with our research results that showed pronounced increase in leaf area with poultry manure application. Richert and Salomon (1998) also observed increased leaf area of lettuce and cabbage when broiler poultry manure was used as the soil organic nutrient amendment. Similar reports by Adewole and Dedeke (2012) noted significant difference in leaf area of *A. cruentus* among different poultry manures fertilization rates. Application of water once per week on the amaranth plants indicated the least total plant leaf area throughout the growing period. An increase of 172.4% and 107.2% in total plant leaf area was observed from 3 to 6 WAT and 6 to 9 WAT respectively, while a decrease of 21% was observed between 9 to 12 WAT. Irrigation frequency of thrice and twice per week significantly increased total plant leaf area by 43.1% and 64.4% respectively over one time application of water per week. These results agree with earlier reports of Olufolaji *et al* (2010) that moisture stress significantly affects leaf area growth and development in amaranth. Through the planting season, interactive effects of poultry manure x irrigation frequency were significant for total plant leaf area.

Table 4. Influence of rate of poultry manure and irrigation frequency on total leaf area (cm^2) per plant of *Amaranthus cruentus*

	Week after transplanting (WAT)			
	3	**6**	**9**	**12**
Poultry manure (t/ha)				
0	887.72c	2006.05d	4482.71d	3417.53d
3.5	1322.22b	3282.52c	6807.60c	5449.03c
7.0	1893.20a	5762.41a	8822.62b	7621.82b
10.5	1842.61a	5012.53b	13457.91a	10038.61a
$LSD_{(0.05)}$	204.13	195.33	242.32	273.98
Irrigation frequency				
Once	1068.50c	2219.61c	6178.02c	5603.23c
Twice	1918.71a	5731.90a	10156.51a	8086.83a
Thrice	1472.04b	4097.42b	8843.63b	6205.12b
$LSD_{(0.05)}$	193.3	218.09	385.96	345.67
PM x R	**	**	**	**

PM- Poultry manure; R - Irrigation frequency
*, ** Significant at 5% and 1% respectively

Components of yield

Performance of yield components of grain amaranth as affected by poultry manure and irrigation frequency is shown in Table 5. Results showed that higher rates of poultry manure significantly increased the length of panicle, dry weight of panicle, 1000 dried seed weight and percent grain moisture at harvest with highest values of 56.2cm, 18.4g, 1.4g and 37.7% respectively at 10.5kg ha^{-1}. Longer panicles were produced with more water to a level and may be attributed to cell growth. Physiologically, increased water availability increases hydraulic force of water which further results in multi-dimensional increase in cell division and elongation (Lukovic, *et al.*, 2009). Conversely limitation of water reduces grain filling leading to reduced panicle and seed weight. Earlier reports with grain amaranth agree with these results (Pérez *et al.*, 2009; Yarnia *et al.* 2013). Three times application showed more percent grain moisture. All the components of yield of amaranth produced highest values with twice irrigation regime. Relative to a one time water application, twice irrigation regime increased the length of panicle, dry weight of panicle, 1000 seed dry weight by 60.5%, 38.6 and 53.3% and 61.5% respectively. Interactive effects of poultry manure x irrigation were significant for all components of yield.

Table 5. Influence of rate of poultry manure and irrigation frequency on yield components of *Amaranthus cruentus*

	Length of panicle (cm)	Dry weight of panicle (g)	1000 dried seed weight (g)	% grain moisture at harvest
Poultry manure (t/ha)				
0	20.70d	9.70c	0.82c	24.31b
3.5	38.51c	12.81bc	1.04b	26.53b
7.0	46.32b	15.05ab	1.43a	34.31a
10.5	56.22a	18.43a	1.41a	37.72a
$LSD_{(0.05)}$	5.13	4.32	0.14	3.56
Irrigation frequency				
Once	30.12c	10.82b	0.71b	23.13c
Twice	48.33a	17.60a	1.54a	31.72a
Thrice	41.61b	13.33ab	1.10b	37.31b
$LSD_{(0.05)}$	5.67	4.44	0.35	4.18
PM x R	**	**	**	**

PM- Poultry manure; R - Irrigation frequency
*, ** Significant at 5% and 1% respectively

Fresh shoot yield, dry matter yield and grain yield

Grain amaranth differed significantly among the poultry manure rates. The highest fresh shoot and dry matter yield of 560.83 and 122.65g per plant respectively were achieved at 10.5kg ha^{-1}. Evaluation of grain yield revealed significant increase among poultry manure treatments from zero level with highest grain yield value recorded 5.83g per plant at 10.5kg ha^{-1}. Significant increase in plant dry weight per plant with corresponding increase in the fertility rate up to a certain level has been reported in related studies (Kalmani *et al.*, 2002; Olaniyi and Ajibola, 2008). Akinwumi *et al.* (2011) reported enhanced grain yield of *A. cruentus* with cured poultry manure. Okoli and Nweke (2015) observed higher fresh and dry shoot weights at higher poultry manure rates (10 to 20t/ha) compared to lower rates of 5t/ha and 0t/ha. The observed enhancement of growth and yield parameters of *A. cruentus* with increased rate of poultry manure could be attributed to its high organic matter content which further promotes the activities of soil biology to release the nutrients for better performance of the plant. Poultry manure contains large quantities of macro and micronutrients for plant growth and development, photosynthate production and biomass gain (Abou-Elmagd *et al*, 2006).

Three times irrigation recorded the highest fresh shoot yield of 512.73g, while the twice irrigation indicated the highest dry matter yield and grain yield of 105.21g and 5.91g respectively (Table 6). Highest grain yield was observed on twice irrigation. The high fresh shoot yield in thrice irrigation relative to once and twice may be due to excessive accumulation of water in the plant tissues which could not translate into dry weight gain. The lower dry weight and grain yield of the crop in thrice relative to twice irrigation may be attributed to excess water application. Generally in the study, vegetative parameters, yield components and grain yield were reduced at thrice irrigation. Payero *et al.* (2008) noted that excessive irrigation has the capacity to reduce the amount of oxygen in the crop root zone and increase the likelihood of nutrient leaching, making less of it available for crop uptake.

Table 6. Influence of rate of poultry manure and irrigation frequency on dry matter yield and grain total production of *Amaranthus cruentus*

	Fresh shoot yield (g/plant)	Dry matter yield (g/plant)	Grain yield (g/plant)
Poultry manure (t/ha)			
0	284.61d	61.59c	2.28c
3.5	383.72c	92.89b	4.31b
7.0	433.80b	100.60b	5.67a
10.5	560.83a	122.65a	5.83a
$LSD_{(0.05)}$	12.67	14.81	1.11
Irrigation frequency			
Once	334.37c	88.64b	3.27c
Twice	400.11b	105.21a	5.91a
Thrice	512.73a	89.43b	4.41b
$LSD_{(0.05)}$	29.34	12.78	0.78
PM x R	**	**	**

PM- Poultry manure; R - Irrigation frequency

*, ** Significant at 5% and 1% respectively

Irrigation Water Use Efficiency

In this study, irrigation water use efficiency (IWUE) varied significantly with water treatments (Table 6). IWUE decreased with frequency of irrigation and increased with rate of poultry manure. Values tended to be higher with once application ranging from 35.14 to 69.14 kgm^{-3} (wet- mass basis) and 7.60 to 15.14 kgm^{-3} (dry-mass basis). Three times weekly application showed the least IWUE with values ranging from 11.72 to 23.08 kgm^{-3} (wet- mass basis) and 2.53 to 5.05 kgm^{-3} (dry-mass basis). Payero *et al.* (2008) also reported decrease in IWUE with irrigation in corn. Maximum IWUE was obtained with the highest poultry manure rate of 10 $kgha^{-1}$ in all the irrigation regimes both on wet-mass and dry-mass basis. The increased development of the root system owing to better translocation of photosynthates to roots based on balanced nutrition from the poultry manure might have resulted in extraction of more moisture from the soil and further contributed to the enhanced IWUE with higher rate of poultry manure. Chaudhari *et al.* (2009) reported maximum water use efficiency with 60 kg N/ha + A*zotobacte*r liquid culture in amaranth.

Table 7 Influence of rate of poultry manure and irrigation frequency on irrigation water use efficiency (kgm^{-3}) of *Amaranthus cruentus*

	Wet-mass	Dry-mass	Wet-mass	Dry-mass	Wet-mass	Dry-Mass
	Irrigation frequency					
	Once		Twice		Thrice	
Poultry manure (t/ha)						
0	35.14	7.60	17.54	3.80	11.72	2.53
3.5	47.37	11.43	23.69	5.72	15.79	3.80
7.0	53.56	12.42	26.78	6.22	17.86	4.14
10.5	69.24	15.14	34.62	7.57	23.08	5.05
LSD (5%)	5.11	2.08	3.51	1.88	4.07	1.13

PM- Poultry manure; R - Irrigation frequency

CONCLUSION

The study evaluated the effect of different poultry manure rates and weekly irrigation frequency on growth attributes, biomass production, yield and irrigation water use efficiency in grain amaranth during the dry season. Increased poultry manure rates above the zero level increased all growth, yield parameters, and irrigation water use efficiency (IWUE). All growth and yield parameters produced their optimum at highest poultry manure rate of 10.5 kg ha^{-1}. Except fresh mass yield and percent grain moisture at harvest, other growth and yield parameters attained their optimum with twice irrigation. The study has shown that twice irrigation with poultry manure rate of 10.5 kg ha^{-1} can give good growth and yield in grain amaranth.

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