ooINFLUENCE OF POULTRY MANURE AND IRRIGATION FREQUENCY ON GROWTH AND YIELD OF GRAIN AMARANTH (*Amaranthus cruentus* L.) IN BADEGGI, NIGER STATE, NIGERIA

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Abstract

Buckets 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 research farm of the National Cereal Research Institute, Badeggi, Niger-State between 7th November 2023 and 7th January 2024. Poultry manure was applied at the rate of 2.5, 5.0, and 7.5 t/ha and Control. The irrigation frequency consists of three artificial irrigation regimes which involve watering once, twice and thrice per week. The experiment was a 4x3 factorial laid in a Randomized Complete Block Design (RCBD) with three replicates. Increased rate of Poultry manures significantly increased Plant height, Leaf area, dry matter yield and grain yield. Highest plant height {216.05 cm}, leaf area {1345.9 cm2}, dry weight Panicle {18.4 g} and grain yield {5.83 g} were obtained at 7.5 t/ha. On the average, twice irrigation indicated the highest vegetative parameters, components of yield and grain yield. Irrigation water use efficiency reduced with increased irrigation frequency.

Keywords: *Poultry manure, Irrigation, Amaranth grain, Water use efficiency.*

Introduction

In 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 a C4 photosynthesis pathway. Its anatomical attributes allow for efficient utilization of carbon dioxide under a wide range of environmental conditions such as moisture stress, temperature (25°C to 40°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 a popularly cultivated vegetable called green vegetable or African spinach. Its cultivation cuts across all parts of Nigeria in the urban and rural areas from the North to the South and is used as both a 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. It's also high in the amino acid Lysine and rich in Iron, Calcium, Potassium and Vitamin A and C (Anon, 2010). Besides its nutritional importance, the cultivation of amaranth has been an income-generating activity for smallholder farmers hence contributing to the livelihood of the low-income population.

Despite its societal importance, cultivation of

A. cruentus has been limited by poor soil nutrients and availability of water, especially in the dry season. Most soil in Nigeria are inherently deficient in organic carbon, acidic and relatively sandy. That explains the current advocacy for the use of organic manure 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 improve soil texture and structure, as well as forming complexes with soil colloids or minerals and will generate long-term positive effects on soil fertility (Ghanbbour and Davis, 2001). Grain amaranth response to soil nutrient applications has been documented by several researchers. Akinwunmi *et al.,* (2011) reported a significant increase in plant height and stem girth, while a combination of Poultry manure and NPK positively improved the 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). The economic and sustainable application of water to achieve maximum crop productivity is termed irrigation. The method to be used depends on local condition such as soil moisture, flow, crop characteristics, topography and acquifer discharge (Adejumobi *et al*, 2015).

In the absence of rainfall, especially in the dry season, poor timing of irrigation can result in crop water deficit leading to water and nutrient deficiency, and delayed crop maturity, which consequently results in poor crop yield. Moisture shortage at the early stage of crop growth results in poor root development, while shortage at the 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 the highest plant height, number of leaves, stem diameter, and pod yield in okra (Adejumobi *et al.*, 2015). Payero *et al.,* (2008) reported that 5-day irrigation frequency conserved 18% and 12% of water at the early stage of tomato development relative to 1 to 3-day frequencies. Even a small amount of irrigation water applied at heading, flowering, and milking stages of growth in sunflower can significantly increase seed yield (Unger, 2003; Stone *et al.,* 2006).

Payero *et al.,* (2008) observed that a sunflower crop which received three irrigations—at heading stage, heading + flowering stage, 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. Efficiency use 2of water use 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 (Payero *et al.,* 2008). 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

Study Site

The buckets experiment was conducted under an open roof during the dry season at the research farm of the National Cereal Research Institute, Badeggi, Niger State between 7th November 2023 and 7th January 2024. The experiment site is within the Southern Guinea Savannah Agro-Ecological Zone of Nigeria {Latitude $9^0 45'$ N and Longitude $7^0 31'$ E}.

Agronomic Practices

The experiment was two factors, combined and arranged in a Randomized Complete Block Design (RCBD) with three replicates. It consists of four poultry manure rates: 0 t/ha, 2.5 t/ha, 5.0 t/ha, 7.5 t/ha and three artificial irrigation regimes at the rate of 750 mL per application time were used and involved watering once, twice, and thrice per week. Amaranth seeds were obtained from IAR/ABU Zaria (Samama 19). 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 9.8 kg of sieved 10 mm Loam soil and placed on a platform 30 cm 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.

Soil and Poultry Manure analysis

Soil samples were collected for determination of both chemical and physical properties before sowing. Also, Poultry manure was collected for determination of chemical and physical properties before planting according to the procedures described by Agberin (1995).

Grain amaranth seeds were sown in a nursery and later transplanted to the buckets after two weeks at the rate of three seedling per bucket. Poultry manure was applied in a single application three days before transplanting.

Growth and Yield Parameters

The growth, yield, phenology and yield component were studied. Plant height determined by measuring the height of each tagged plant from the soil level to the tip of the plant terminal bud. Number of leaves per plant was obtained by counting all functional leaves per plant on the tagged plants. 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 (2000).

LA=0.5049[L×W×0.4786], where by uprooting and harvesting three plants at 9 WAT {9 weeks after transplanting} from each pot. Roots of plants were properly washed to remove soil. Whole plants were oven dried at a temperature of 72∘C for 48 hours.

Yield and yield components parameters collected were length of panicle determined by measuring using a meter rule on tagged plants. The number of panicles was determined by physical counting of panicles on the tagged plant. 1000 dried seed weight was determined by weighing. Panicle dry weight and percent moisture of grain at harvest were also determined.

Grain yield (kg/ha) was calculated as:

Grain Yield (kg/ha)=bucket size in square metresbucket yield (g)×10,000

Irrigation Water Use Efficiency {IWUE} of the crops was estimated using the following formula (Payero *et al.,* 2008, Abubakar *et al.,* 2016):

IWUE=DMY/CMW

where:

- **IWUE** = Irrigation Water use efficiency (kg/m3)
- **DMY** = dry mass of whole plant (kg)
- **CMW** = accumulative amount of irrigation water applied (m3)

Statistical Analysis

Data obtained from the study were subjected to Analysis of Variance (ANOVA) appropriate for a factorial arranged RCBD pattern according to Steel and Torrie (1980). The least significant difference (LSD) at the 5% level of probability was used for the separation of treatment means for significant differences.

Results and discussion

Physical and chemical Properties of the soil before sowing

Table 1 presented results of Physical and chemical properties of the soil prior to sowing. The result revealed that the soil texture was sandy loam for the two cropping seasons, slightly acidic in water which makes it suitable for plant growth because of the availability of plant nutrient for plant uptake at pH 5.5 to 6.5 {Brady and Weil, 2002}. The results showed that the soil was low in inorganic carbon, available phosphorus and low in Nitrogen.

Chemical Properties of Poultry Manure Used for the Experiment

Table 2 shows the nutrient content of organic manure {Poultry manure} used in the study. The poultry manure was slightly acidic. The organic matter, total nitrogen and available phosphorus content were sufficient for the two cropping seasons. The Na, Zn, Mn concentration were low. {Table 2}.

Influence of Poultry Manure and Irrigation frequency on Plant height.

Table 3 indicated that Poultry manure and irrigation frequency had significant effect (P<0.05) on Plant height. Tallest plants were consistently observed on 7.5 t/ha of Poultry Manure with maximum plant height of 216.05 cm at (12 WAT) weeks after transplanting while the control had the shortest plant height (151.3 cm). 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 Ojekoh and Bisong (2011) had earlier obtained similar increase in plant height with increase in application Poultry manure and Organomineral respectively on *Amaranthus 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.

Influence of Poultry Manure and irrigation frequency on number of Leaves.

Table 4 indicated that 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 7.5 kg/ha and decreased thereafter. 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 *Amaranthus cruentus* (Makinde, 2007; Adewale and Dedeke 2012). Oyedeji *et al.,* (2014) also observed more leaves with *Amaranthus cruentus* 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. Yarima *et al*, (2013) observed reduced number of leaves with low irrigation regimes in amaranth. Moisture availability can also reduce the aging and falling of leaves and consequently increase the leaf number of the plant (Prasad and Staggenborg 2008) Poultry manure x irrigation frequency interactions were significant for plant height up till 12 WAT.

Influence of poultry manure and irrigation Frequency on total leaf area (cm2) **Per Plant of *Amaranthus cruentus***

Table 5 indicated both poultry manure rate and irrigation frequency had significant effect on total leaf area of grain amaranth. At 9 WAT, poultry manure increased total plant leaf area by 34.2%, 96.8% and 200% at 2.5 t/ha, 5.0 t/ha and 7.5 t/ha respectively when compared to the control. Poultry manure rate of 7.5 t/ha recorded maximum leaf area (1345.9 cm2). Earlier research reports also agree with our research results that showed pronounced increase in leaf area with poultry manure application. Richert and Solomon (2010) also observed increased leaf area of Lettuce and Cabbage when poultry manure was used as the soil organic nutrient amendment. Similar reports by Adewale and

Dedeke (2012) noted significant difference in leaf area of *Amaranthus cruentus* among different poultry manure 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 107.7% 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 WAT to 12 WAT. Irrigation frequency of thrice and twice per week significantly increased total 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 *Amaranthus cruentus*. Throughout the planting season interactive effects of poultry manure X irrigation frequency were significant for total plant leaf area.

Influence of Poultry manure and irrigation frequency on Component of Yield.

Table 6 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 56.7cm, 18.4g, 1.4g and 37.7% respectively at 7.5t/ha. Longer panicles were produced with more water to a level and 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.,* 2010). Conversely limitation of water reduces grain filling leading to reduced panicle and seed weight. Earlier reports with grain *Amaranthus cruentus* agree with these results (Perez *et al.,* 2010, Yarmia *et al.,* 2013). Three times application showed more percent grain moisture. All the components of yield of *Amaranthus cruentus* 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 components of yield.

Influence of Poultry manure and irrigation frequency on dry matter yield, fresh shoot yield and grain total Production

Table 7 showed highest fresh shoot and dry matter yield of 560.83g and 122.65g per plant respectively were achieved at 7.5t/ha of Poultry manure

Evaluation of grain yield revealed from zero level with the highest grain yield value recorded at 5.83 g per plant at 7.5 t/ha. A significant increase in plant dry weight per plant with a corresponding increase in the fertility rate up to a certain level has been reported in related studies (Kinwumi *et al.,* 2011) reported enhance grain yield of *Amaranthus cruentus* with Poultry manure. Okoli and Nweke (2015) observed higher fresh and dry shoot weight at higher poultry manure rates {10 to 15 t/ha} compared to lower rates of 5 t/ha and 0 t/ha. Poultry manure contains large quantities of macro and micronutrients for plant growth and development, photosynthate production and biomass gain (Abon-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 7). 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 (Din *et al*, 2011). The lower dry weight and grain yield of the crop in thrice relative to twice irrigation may be attributed to excess water application (Payero *et al*, 2008). 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.

Influence of Poultry manure and irrigation frequency on irrigation Water use efficiency {kg/m^3} of *Amaranthus cruentus*

Table 8 showed Irrigation Water Use Efficiency {IWUE} decreased with the frequency of irrigation and increased with the rate of poultry manure. Values tended to be higher with once application, ranging from 35.14 kg·m^3 to 69.14 kg·m^3 {wet mass basis} and 7.60 kg·^{3} to 15.14 kg·m^3 {dry-mass basis}. Three times weekly application showed the least IWUE with values ranging from 11.72 kg·m^3 to 23.08 kg·m^3 {wet-mass basis} and 2.53 kg·m^3 to 5.05 kg·m^3 {dry-mass basis}. Payero *et al.,* (2008) also reported a decrease in IWUE with irrigation in corn. Maximum IWUE was obtained with the highest poultry manure rate of 7.5 t/ha in all the irrigation regimes, both on a 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 the extraction of more moisture from the soil, and further contributed to the enhanced IWUE with a higher rate of poultry manure. Chaudhari *et al.,* (2009) reported Maximum water use efficiency with 60 kg N/ha + Azotobacter Liquid Culture in *Amaranthus cruentus*.

Conclusion

Increased poultry manure rates above zero level increased all growth, yield parameters and irrigation water use efficiency {IWUE}. Therefore, twice irrigation with a poultry manure rate of 7.5 t/ha guarantees high productivity and yield in grain amaranth in Badeggi, Niger State, Southern Guinea Savanna Agro-ecological Zone of Nigeria.

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Table 1. Physical and chemical properties of the soil before sowing.

Parameter	Value (2023)	Value (2024)
Sand (g·kg−1)	622	610
Silt (g·kg−1)	102	140
Clay (g·kg−1)	246	250
Textural classes	Sandy Loam	Sandy Loam
pH in H_2O (1:2.5)	5.32	6.55
Total N (cmol·kg−1)	0.20	0.31
Available P (mg·kg−1)	8.00	8.37
Organic Carbon (cmol·kg−1)		
Mg^{2+}	1.02	1.12
Ca^{2+}	2.14	2.72
K^{+}	0.41	0.53
Na^{+}	0.27	0.38
Exchangeable Cation (cmol·kg−1)		
ECEC (Cmol·kg−1)	3.90	4.13

Source: *Soil Sample analysed by Soil Department, Federal University of Technology, Minna.*

Table 2. Chemical properties of Poultry manure used for experimental trial

Parameter	**Value**	
Parameter	2023	2024
pH In H_2O	5.80	5.90
Organic Carbon (g/kg)	17.8	18. 22
Total N (g/kg)	3.60	4.20
Available P. (mg/kg)	1.50	1.90
K^{+}	14.70	16.80
Ca^{2+}	21.10	23.40
Mg^{2+}	3.80	4.30
Na^{+}	2.50	2.80
Fe	12.00	13.50
Ca	21.10	22.30
Mn	0.60	0.70

Source: *Poultry manure as analyzed by Soil Dept, Federal University of Technology Minna.*

Table 3. Influence 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	38.51c	126.62d	151.31d
2.5	30.33b	63.12b	130.90c	170.30c
5.0	41.32a	78.60a	142.61b	199.12b
7.5	47.11a	80.61a	158.10a	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	72.81a	141.62a	188.80b
LSD(0.05)	5.41	4.60	7.42	17.82
PM x R	**	**	**	**

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

Table 4. Influence 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	20.00b	38.23d	30.92d
2.5	16.83ab	23.71b	46.32c	38.63c
5.0	18.82a	38.60a	58.70b	49.33b
7.5	18.31a	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	31.15a	63.33a	51.70a
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
- ns: Not significant

Table 5. Influence rate of poultry manure and irrigation frequency on total leaf area (cm2) 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
2.5	1322.20b	3282.52c	6807.60c	5449.03c
5.0	1693.22a	5762.41b	8802.02b	7612.33b
7.5	1842.21a	5012.31a	13457.91a	10076.11a
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	8083.83a
Thrice	1472.04b	5041.02b	8641.83b	6595.73b
LSD(0.05)	93.11	218.09	386.90	345.67
PM x R	**	**	**	**

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

Table 6. Influence 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	12.30bc	1.04b	26.53b
5.0	46.22b	15.05ab	1.11a	34.31a
7.5	56.72a	18.43a	1.43a	37.72a
LSD(0.05)	5.13	4.32	0.14	3.56
Irrigation frequency				
Once	30.12c	10.82b	0.71b	23.13b
Twice	48.33a	17.60a	1.54a	31.22a

Table 7. Influence 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
2.5	383.72c	92.01b	4.31b
5.0	433.80b	100.60b	5.67a
7.5	560.83a	122.65a	5.83a
LSD(0.05)	12.67	14.81	1.11
Irrigation frequency			
Once	334.27b	88.64b	3.27c
Twice	400.11c	105.21a	5.91a
Thrice	512.73a	95.33b	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

Table 8. Influence rate of poultry manure and irrigation frequency on irrigation water use efficiency (kg ·m−3) of *Amaranthus cruentus*

	Once		**Twice**		**Thrice**	
Poultry manure (t/ha)	**Wet-mass**	**Dry-mass**	**Wet-mass**	**Dry-mass**	**Wet-mass**	**Dry-mass**
0	35.14	7.60	17.54	3.80	11.72	2.53
2.5	47.37	11.43	23.69	5.72	15.79	3.81
5.5	53.18	13.84	26.59	6.92	17.73	4.61
7.5	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