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Yield of Vegetable Amaranth (*Amaranthus Cruentus* L.) as Influenced by Row Spacing and Nitrogen Fertilizer in Mubi, Northern Guinea Savannah Zone of Nigeria

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ABSTRACT
This field study was carried out at Food and Agricultural Organization / Tree Crop Programme (FAO/TCP) Teaching and Research Farm, Faculty of Agriculture, Adamawa State University, Mubi, Northern Guinea Savannah zone of Nigeria, on sandy loam soil, to study the yield of vegetable amaranth (Amaranathus cruentus L.) as influenced by row spacing and nitrogen fertilizer in 2012 and 2013 rainfed cropping seasons. The experiment involved three levels of row spacing (20, 30, and 40 cm) and five levels of N fertilizer (0, 30, 60, 90, and 120 kg ha^{-1}). These treatments in a factorial combination were laid out in a Randomized Complete Block Design and replicated three times. Data were collected on yield parameters. Data generated were analyzed using Analysis Of Variance (ANOVA). Results show that fresh weight, dry matter weight, absolute crop growth rate ($plant^{-1}$) of vegetable amaranth increased significantly (P = 0.05) as row spacing and applied N rate was increased. On unit area basis however, fresh yield increased as the applied N increased and row spacing decreased. Therefore, the optimum N rate and row spacing for the maximum yield of vegetable amaranth (Amaranthus cuentus L.) is 120 kg N ha^{-1} at 20 cm inter row spacing and was judged the best combination for the production of vegetable amaranth in the Northern Guinea Savannah zone of Nigeria. The study recommends the adoption of the application of 120 kg N ha^{-1} for highest growth and yield of vegetable amaranth.
Keywords: Vegetable Aamaranth, Yield, Nitorgen Fertilizer, Row Spacing, Influence

INTRODUCTION

Amaranthus cruentus L. is a tall annual herb topped with cluster of dark pink flower and can grow up to 2 m in height (Stallknecht and Schulz – scheaffer, 1993). It is one of the three amaranthus species cultivated as vegetable and grain source. The other two are *Amaranthus* caudatus L. and *Amaranthus hypochondriacus* L. (Olaniyi, 2007; Olaniyi *et al*., 2008).

Amaranthus which is a multicultural herb is an annual crop plant collectively known as Amaranth. Estimated, 60 species are recognized with inflorescence and foliage ranging from purple and red to gold (Grubben and Denton, 2004). The herb, which is native to Central and South America, is one of the important underutilized crop. It is widely cultivated in various regions of the world as well as in Nigeria as food and leafy vegetable (Smitha, 2010). The crop belongs to the family *Amaranthaceace* and genus Amaranthus. There is no clear deference between the vegetable type and grain type (Olaniyi, 2007). The leaves are nutritionally significant source of minerals included vitamin A, vitamin B_6, vitamin C and vitamin K (Grubben and Denton, 2004). Amaranth has a very high nutritional value, higher grain protein (13 – 19 %) and leaf protein (23 – 25 %) with high lysine and sulphur containing amino acids, which are limiting in other conventional crops (Joshi and Rana, 1995). Amaranth has been used for food by human in a number of ways. The grain is grind into flour for use in bread, noodles,

pancake, cereals, granola, cookies and other flour based product (Putnam, 1990). Several studies have shown that, like Oats, amaranth is beneficial for people with hypertension and cardiovascular disease. Regular consumption reduces blood pressure and cholesterol level which improved antioxidant stages and some more immune parameters (Olaniyi, 2007; Olaniyi *et al*., 2008; Kolawole and Sarah, 2009). It is also a potential source of forage (9.9 – 12.7 t ha^{-1}) dry matter as well as 74 – 148 t ha^{-1} of silage (80 % moisture) (Putnam *et al*., 1989). The yield of the vegetable crops is generally determined by so many factors, including plant nutrient and proper spacing. Nitrogen fertilizer is known to have been one of the plant nutrients that influence vegetative growth in most crops and subsequently increased yield.

Fertilizers are soil amendments applied to promote plants growth. The main nutrients present in fertilizers are nitrogen (N), phosphorus (P) and potassium (K) (macro nutrients), and other nutrients (micro nutrients) are added in smaller amount (Merger, 2010). Nitrogen fertilizers promote vegetative growth and impart the characteristics of deep green colour essentially for photosynthesis (Futuless and Bagale, 2007). The Optimum N amount reported for maximum amaranthus growth ranges from 45 kg to 100 kg N ha^{-1} (Olaniyi, 2007). This study focuses on the yield of vegetable amaranth (Amaranthus Cruentus L.) as influenced by row spacing and nitrogen fertilizer in Mubi, Northern Guinea Savannah Zone of Nigeria, and specifically evaluates the effects of different levels of N fertilizer and row spacing on the yield of the vegetable amaranth.

MATERIALS AND METHODS

Experimental Site

Two years field experiments were conducted at the Teaching and Research Farm, Food and Agriculture Organization/Tree Crop Programme (FAO/TCP) farm, Faculty of Agriculture, Adamawa State University, Mubi, Nigeria. It was conducted under rain-fed condition in 2012 and 2013 cropping seasons. Mubi, located in the Northern Guinea Savannah of Nigeria is situated between latitude 10^0 10" and 10^0 30" North of the Equator and between longitude 13^0 10" and 13^0 30" E of the Greenwich meridian and at an altitude of 696 m above mean sea level (MSL). The annual mean rainfall of Mubi is 900 mm, and a minimum temperature of 18^0C during harmatan period and 40^0C as maximum in April (Adebayo, 1990).

Soil Sampling

The composite soil samplings were collected from 0 -15 cm and 15 – 30 cm depth using soil auger at three different locations before ploughing. Soil samples were air dried, grounded and allowed to pass through 2 mm sieve and were analyzed for routine physical and chemical properties using standard laboratory procedures.

Previous Crops Grown on the Experimental Area

During 2010 and 2011 raining seasons, rossele and tomatoes were grown on the field of the experimental site with appropriate agronomic practices.

Experimental Design

Treatments

There were 15 treatment combinations consisting of three rows spacing and five levels of nitrogen fertilizer.

Field Design and Layout

The treatments were factorially combined and the experiment was laid out in a Randomized Complete Block Design (RCBD), which was replicated three times.

Land Preparation

The land was prepared using tractor drawn plough once and leveled manually. The smoothened land was laid out according to experimental design.

Germination Test

Germination test was carried out according to International Seed Testing Association (1985) standard. This was done by randomly counting 25 amaranth seeds from pure seeds. The 25 pure seeds were placed in a petri dish containing filter paper soaked with distilled water. Germination count was made every day up to the completion of germination. A seed was considered to have germinated when the seed coat raptured, plumule and radical came out up to 2 mm length.

Source of Seed and Sowing

The amaranth seed for this research (variety NH 84/445) was obtained from National Institute of Horticultural Research (NIHORT, Ibadan). The seeds were sown by drilling according to the treatments of the spacing (20 cm, 30 cm and 40 cm, respectively) and later thinned to 5 cm between plants at one week after emergence (WAE).

Fertilizer Applications

Single Super Phosphate (SSP) fertilizer was applied at the rate of 45kg P_2 O_5 ha^{-1} to all the experimental plots during land preparation and the N Fertilizer was applied in the form of Urea (46 %). The amount of the urea needed for each plot was calculated based on the treatment for the N fertilizer using $Q = \frac{R}{100n} \times \frac{A}{1}$ (Avav and Ayuba, 2006).

Where Q = amount of fertilizer required,
R = recommended rate of nutrient element,
n = analysis or grade of fertilizer (%) and
A = Area (m^2).

Half of the N fertilizer for each treatment was applied at the time of sowing by drilling in small furrows opened manually 10 cm away from the seed line and covered with soil to avoid the losses. The remaining half of the N was applied at 3 weeks after sowing (WAS).

Weeds and Insects Pest Control

Weed control in amaranth was achieved by cultivation, hand weeding, delayed planting and by manipulation of plant population using narrow rows spacing as there are no herbicides presently labeled for weed control in amaranth (Stallknecht and Schaeffer, 1993; Putnam *et al*., 1989). In this research, hand weeding was carried out at two weeks interval from 2 WAS. Incidence of corn ear worm, *Heliothis zea* and cowpea weevil *Aphids craceavora* was controlled using cypermetrin 10 EC insecticide at the rate of 800 ml ha^{-1}. The chemical persistence of the insecticide is usually 72 hrs.

Harvesting

Vegetable yield was determined by weighing the plants from each net plot and the weighted was converted to a yield per hectare.

Plant Sampling and Collection of Data

A sample consisting of ten plants was selected and tagged at random from each net plot for recording various biometric observations at 3 and 6 WAS as follows:

Absolute Crop Growth Rate (ACGR) (g wk^{-3})

ACGR of a unit area of a canopy cover at any instance in time (t) is the increase of plant material per unit of time (Radford, 1967) or rate at which dry weight of the whole plant increases. This was determined as ACGR = $(\frac{W2-W1}{T2-T1})$ where, W_1 and W_2 are shoots dry weight which was taken at two consecutive harvest over time interval T_1 and T_2.

Fresh Plant Weight (g)

Fresh vegetable weight was determined from sub plots and final vegetable yield was determined by harvesting the whole net plot of each treatment. The weight was converted to the yield per hectare.

Plant Dry Matter Weight (g)

Destructive harvesting of five plants from border rows of each treatment was done. The chopped up leaves and stems was dried at a temperature of 65^0C in an air dry oven until constant weight was obtained. Thereafter, the dry weight was taken.

Statistical Analysis and Interpretation of Data

Analysis of variance was carried out on each of the data recorded for each year of study, followed by combined analysis over two years using Statistical Analysis Software (SAS) system 2008 (version 9.2). Mean values were subjected to Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Physical and Chemical Properties of soil of the Experimental Site

The experimental site was characterized by sandy loam soil with a normal pH of 6.40 in 2012 and 6.50 in 2013 and low available nitrogen of 0.18 g N kg^{-1} (2012) and 0.17 g N kg^{-1}(2013), medium available phosphorus of 6.67 g kg^{-1} (2012) and 6.80 g kg^{-1} (2013). The soil also has high available potassium of 0.45 C mol kg^{-1} (2012) and 0.46 C mol kg^{-1} (2013) as presented in Table 1.

Table 1: Soil Physical and chemical properties of the experimental site, 0-15 cm and 15-30 cm depth.

Particular		*2012*		*2013*	
I.	**Physical properties**				
A.	Particles size distribution (%)				
	Clay		14.2		14.1
	Silt		31.6		32.8
	Sand		54.2		53.1
B.	Textual class		*Sandy Loam*		*Sandy Loam*
II.	**Chemical Properties**				
	pH (1:2 soil : water solution)		6.40		6.50
	Organic carbon (kg^{-1})		3.7		3.8
	Cat ion exchange capacity [c mol (+) kg^{-1}]	3.25		3.40	
	Available nitrogen (g N kg^{-1})		0.18		0.17
	Available phosphorus (mg P kg^{-1})	6.67		6.82	
	Available potassium [c mol (+) kg^{-1}]		0.45		0.46
	Available magnesium [c mol (+) kg^{-1}]	0.43		0.41	
	Available sodium [c mol (+) kg^{-1}]	0.36		0.35	
	Available calcium [c mol (+) kg^{-1}]	1.90		1.92	

Source: Field experiment (2012/2013)

Fresh Plant Weight (g $plant^{-1}$)

The effect of nitrogen fertilizer on fresh weight of amaranthus plant was highly significant at all the growth stages in both the two years of the experiment and the combined seasons. Fresh plants weight of vegetable amaranth increased with increased rate of N fertilizer up to 120 kg N ha^{-1} which recorded the highest mean values, followed by 90 kg N ha^{-1}. The lowest mean value was recorded in 0 kg N ha^{-1}.

The row spacing also recorded higher significant effect. Row spacing of 40 cm recorded significantly more fresh plant weight, followed by 30 and 20 cm row spacing, respectively (Table 2). The result was in conformity with the findings of Keskar *et al*.(1981) and Ramachandra and Thimmaraju (1983).

Table 2: Mean Fresh Plant Weight (g) Per Plant of *Amaranthus cruentus* L as Influenced by Row Spacing and N Fertilizer in 2012, 2013 Raining Seasons and Combined

TREATMENTS	**3 WAS**			**6 WAS**		
	2012	**2013**	**COMBINED**	**2012**	**2013**	**COMBINED**
N Fertilizer(kg ha^{-1})						
0	1.70 ^{e}	1.96^{e}	1.83^{e}	24.55^{e}	23.70^{e}	22.12^{e}
30	4.67^{d}	4.95^{d}	4.81^{d}	44.46^{d}	43.39^{d}	43.93^{d}
60	10.38^{c}	10.48^{c}	10.43^{c}	54.72^{c}	53.88^{c}	54.30^{c}
90	16.24^{b}	16.37^{b}	16.31^{b}	69.74^{b}	69.02^{b}	69.38^{b}
120	21.61^{a}	22.08^{a}	21.84^{a}	100.02^{a}	98.53^{a}	99.28^{a}
SE ±	**0.133**	**0.180**	**0.112**	**0.350**	**0.217**	**0.206**
Level of Significance	*	*	*	*	*	*
Row Spacing (cm)						
20	9.00^{c}	1.15^{c}	9.08^{c}	46.39^{c}	45.58^{c}	45.98^{c}
30	10.82^{b}	11.05^{b}	10.94^{b}	57.99^{b}	57.20^{b}	57.59^{b}
40	12.95^{a}	13.30^{a}	13.12^{a}	71.72^{a}	70.34^{a}	71.03^{a}
SE ±	**0.103**	**0.139**	**0.087**	**0.271**	**0.169**	**0.160**
Level of Significance	*	*	*	*	*	*

Mean value with the same letters in each treatment group are not statistically significantly different at P =O.05 (DMRT).

* = statistically significant difference at 5% level of probability.

WAS = Weeks after sowing
N = Nitrogen
SE± = Standard error
Source: Field experiment (2012/2013)

Plant Dry Matter Weight (g Plant-1)

There was highly significant effect of N fertilizer on dry matter accumulation of amaranthus. Application of 120 kg N ha-1 recorded more dry matter accumulation per plant. This was followed by 90 kg N ha-1. Least mean value was obtained in 0 kg N ha-1 (Table 3). Response of row spacing to dry matter accumulation per plant of amaranthus also followed the same pattern. Dry matter accumulation increases with increased in row spacing up to 40 cm which recorded significantly more total dry matter accumulation per plant than 30 and 20 cm row spacing, respectively. This agrees with Singh and Whitehead, 1996; Egharevba and Ogbe, 2002 Olaniyi, 2007; and Jombo et al., 2012.

Table 3: Mean Plant Dry Matter Weight (g) Per Plant of *Amaranthus cruentus* L as Influenced by Row Spacing and N Fertilizer in 2012, 2013 Raining Seasons and Combined

TREATMENTS	**3 WAS**			**6 WAS**		
	2012	**2013**	**COMBINED**	**2012**	**2013**	**COMBINED**
N Fertilizer(kg ha^{-1})						
0	0.51^{e}	0.49^{e}	0.50^{e}	3.43^{e}	3.43^{e}	3.43^{e}
30	1.11^{d}	1.04^{d}	1.08^{d}	5.82^{d}	5.58^{d}	5.70^{d}
60	1.98^{c}	12.46^{c}	2.22^{c}	7.43^{c}	7.74^{c}	7.59^{c}
90	3.18^{b}	3.40^{b}	3.29^{b}	9.89^{b}	10.00^{b}	9.94^{b}
120	4.15^{a}	5.91^{a}	5.03^{a}	13.80^{a}	13.53^{a}	13.67^{a}
SE ±	**0.025**	**0.055**	**0.030**	**0.091**	**0.072**	**0.058**
Level of Significance	*	*	*	*	*	*
Row Spacing (cm)						
20	1.79^{c}	2.05^{c}	1.92^{c}	6.33^{c}	6.40^{c}	6.36^{c}
30	2.18^{b}	2.29^{b}	2.23^{b}	7.99^{b}	7.96^{b}	7.98^{b}
40	2.60^{a}	3.64^{a}	3.12^{a}	9.91^{a}	9.82^{a}	9.86^{a}
SE ±	**0.019**	**0.043**	**0.024**	**0.070**	**0.056**	**0.045**
Level of Significance	*	*	*	*	*	*

Mean value with the same letters in each treatment group are not statistically significantly different at P =O.05 (DMRT).
* = statistically significant difference at 5% level of probability.
WAS = Weeks after sowing
N = Nitrogen
SE± = Standard error
Source: Field experiment (2012/2013)

Harvestable Fresh Yield (t ha^{-1})

The result of harvestable fresh yield of *Amaranthus cruentus* L is presented in Table 4. In all the two years of the experiment and in the combined, harvestable fresh yield of vegetable amaranth increased significantly as the applied N fertilizer rate increased up to 120 kg N ha^{-1} which recorded more harvestable fresh yield. These were followed by 90 kg N ha^{-1} , 60 kg N ha^{-1} , 30 kg N ha^{-1}and the least value was obtained 0 kg N ha^{-1}.
The row spacing of 40 cm produced significantly more harvestable fresh yield. These were followed by 30 and 20 cm row spacing, respectively. Mean harvestable yield decreased with increased row spacing (Table 4).

Table 4: Mean Harvestable Fresh Yield (t ha^{-1}) of *Amaranthus cruentus* L as Influenced by Row Spacing and N Fertilizer at 6 WAS in 2012, 2013 Raining Seasons and Combined

TREATMENTS	2012	2013	COMBINED
N Fertilizer(kg ha^{-1})			
0	16.44^{e}	15.11^{e}	16.11^{e}
30	30.11^{d}	29.33^{d}	29.72^{d}
60	37.89^{c}	37.11^{c}	37.50^{c}
90	47.56^{b}	47.22^{b}	49.39^{b}
120	67.33^{a}	66.22^{a}	66.78^{a}
SE ±	**0.354**	**0.222**	**0.209**
Level of Significance	*	*	*
Row Spacing (cm)			
20	45.39^{a}	45.00^{a}	45.47^{a}
30	38.13^{b}	37.73^{b}	37.93^{b}
40	35.53^{c}	34.67^{c}	35.10^{c}
SE ±	**0.274**	**0.172**	**0.162**
Level of Significance	*	*	*

Mean value with the same letters in each treatment group are not statistically significantly different at P = 0.05 (DMRT).
* = statistically significant difference at 5% level of probability.
WAS = Weeks after sowing
N = Nitrogen
SE± = Standard error
Source: Field experiment (2012/2013)

Matrix of Correlation among Vegetative Characters at 6 WAS

The relationship between fresh yield and vegetative characters of *Amaranthus cruentus* L. are presented in Table 6. The result showed that harvestable fresh yield of vegetable amaranth was positively and strongly correlated to plant fresh weight, plant dry matter accumulation and absolute crop growth rate (r = 0.713, 0.665, 0.784, 0.656, 0.912, 0.780, 0.783 and 0.695 respectively). The result agreed with the findings of Kolawole and Sarah (2009) who indicated that foliage production showed a steady increase in treatment combination of planting density (row spacing) and fertilizer application; yield and plant fresh weight and plant dry matter accumulation. These are directly related. Leaf area index increased significantly as row spacing decreased and N fertilizer rate increased.

Table 5: Matrix of correlation showing the associations among vegetative characters, in the combined season's of 2012 and 2013.

	FYD	*FPW*	*PDMW*	*ACGR*
FYD	1.0000			
FPW	0.78039* *	1.0000		
PDMW	0.78267*** ***	0.99100*** ***	1.0000	
ACGR	0.69468*** ***	0.92155*** ***	0.94328*** ***	1.000

FYD = Fresh yield
PH = Plant height
FPW = Fresh plant weight
PDMW = Plant dry matter weigh
A**CGR** = Absolute crop growth rate
*** *** = Highly significant
Source: Field experiment (2012/2013)

CONCLUSION AND RECOMMENDATIONS

Application of 120 kg N ha-1 at 40 cm row spacing had positive effects on all yield parameters. There was linear increased in all the yield parameters as N-fertilizer and row spacing increased. The effect of increased in N Fertilizer observed to be more pronounced with increased in row spacing. However, Increase in N fertilizer alone without decrease in row spacing depressed yield. Application of 120 kg N ha-1 at 20 cm inter row spacing had the highest harvestable fresh yield of 73.33 t ha-1 (2012), 71.33 t ha 1 (2013) and 72.33 t ha 1 (combined).

Significant higher association between vegetable yield and other growth components was recorded in both years of the experiment and in the combined. Harvestable fresh yield were least in plants without the application of N fertilizer in both cropping season.

In Northern Guinea Savannah zone of Nigeria, significantly higher harvestable fresh yield (72.33 t ha 1) of *Amaranthus cruentus L.* can be obtained with the application of 120 kg N ha-1 at 20 x 5 cm inter and intra row spacing.

RECOMMENDATIONS

From the result, the following recommendations were made:

i. application of 120 kg N ha-1 provided highest growth and development of vegetable amaranth and should be adopted;
ii. farmers should use 20 cm inter row spacing for planting density;
iii. farmers are to be encouraged to use inorganic fertilizer (urea) in the production of vegetable amaranth. This is because urea has faster rate of nutrient release;
iv. for highest yield of vegetable amaranth (*Amaranthus cruentus L.),* application of 120 kg N ha-1 at 20 x 5 cm spacing be adopted by farmers in Mubi, the Northern Guinea Savannah zone of Nigeria; and
v. more researches should be carried out in this direction by increasing row spacing and increasing the rate of N fertilizer; and by decreasing row spacing and increasing N fertilizer rate in same crop and other leafy and fruit vegetables.

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