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

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Abstract
A field experiment was conducted at Food and Agriculture 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 growth and 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 growth parameters. Data generated were analyzed using Analysis Of Variance (ANOVA). Result show that Plant height, number of leaves, stem girth, leaf area, leaf area index, absolute crop growth rate (plant^{-1}) of vegetable amaranth increased significantly ($P = 0.05$) as row spacing and applied N rate was increased. On a unit of area basis however, growth increased as the applied N increased and row spacing decreased. Therefore, the optimum N rate and row spacing for the maximum growth of vegetable amaranth (Amaranthus cuentus L.) is 120 kg N ha^{-1} at 20 cm inter row spacing and was adjudged the best combination for the production of vegetable amaranth in the Northern Guinea Savannah zone of Nigeria. Application of 120 kg N ha^{-1} provided highest growth and development of vegetable amaranth and should be adopted
Key words: Vegetable amaranth, growth, Nitrogen fertilizer, row spacing, influence

INTRODUCTION

Amaranthus, collectively known as Amaranth is a cosmopolitan genus of herbs. Approximately, 60 species are recognized with inflorescence and foliage ranging from purple and red to gold (Grubben and Denton, 2004). Amaranth *(Amaranthus spp.*) is one of the important underutilized crop native to Central and South America. 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 dividing line between a vegetable type and grain type (Olaniyi, 2007). The leaves of vegetable amaranth 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). *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). The growth of the vegetable crops is generally determined by so many climatic, agronomic and soil factors such as plant nutrient and proper spacing. Nitrogen fertilizer is known to have significant influence on vegetative growth of 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 Growth 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 planting density (row spacing) on growth vegetable amaranth and the effects of different levels of N fertilizer on the growth of the plant.

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 N fertilizer.

Field Design and Layout

The treatments were factorially combined (5 x 3) 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 rapture, 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, 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.

Collection of Data and Plant Sampling

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:

Plant Height (cm)

Plant height was measured from the ground level to the end of terminal bud using meter rule, their mean was calculated and recorded.

Number of Leaves

Numbers of leaves from ten sampled plants were counted and their mean was determined and recorded.

Stem Girth (mm)

The stem girth of the tagged plants from each net plot was determined using electronic digital venire caliper; their mean was calculated and recorded.

Leaf Area (mm^2)

Leave area of the whole sampled plants was determined by measuring the individual leaf length and width and multiply by 0.64 (Kolawole and Sarah, 2009) and the result obtained was recorded.

This is the ratio of the total area of leaves to the ground area occupied by the crop (Forbes and Watson, 1992). Thus, LAI = $\frac{LA}{GA}$

Where LA =leaves area and GA = ground area.

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.

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 Soil of the experimental site was sandy loam. The soil had a normal pH (6.40 in 2012 and 6.50 in 2013) with 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) 6.80 g kg^{-1} (2013) and 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

Plant Height (cm)

The result on plant height at 3 and 6 WAS is presented in Table 2. At all the growth stages, in both the two seasons and the combined height of *amaranthus* increased as the applied N fertilizer increased up to 120 kg N ha^{-1}. Application of 120 kg N ha^{-1} recorded significantly higher plants than all other treatments. This was followed by 90 kg N ha^{-1} which produced considerably taller plants than the remaining treatments. Plants treated with 0 kg N $^{-1}$ha recorded the lowest plant height.

Similarly, the result showed that the height of *amaranthus* increased as inter row spacing increased. The highest plant height was recorded in 40 cm inter row spacing, followed by 30 and 20 cm, respectively. The result on Plant height was in contrast to the finding of singh and Whitehead (1993), Oluwaseun (2012), who observed significantly tallest plants in closest spacing.

Table 2: Mean Plant Height (cm) 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	6.45^{e}	6.26^{e}	6.36^{e}	32.43^{e}	33.95^{e}	33.20^{e}
30	13.67^{d}	13.88^{d}	13.77^{d}	35.92^{d}	36.37^{d}	36.14^{d}
60	15.95^{c}	15.96^{c}	15.94^{c}	38.96^{c}	39.40^{c}	39.18^{c}
90	17.92^{b}	17.80^{b}	17.86^{b}	47.97^{b}	49.93^{b}	48.95^{b}
120	22.28^{a}	22.28^{a}	22.28^{a}	66.71^{a}	65.32^{a}	66.02^{a}
SE ±	0.122	0.117	0.030	0.230	0.298	0.189
Level of Significance	*	*	*	*	*	*
Row Spacing (cm)						
20	13.46^{c}	13.44^{c}	13.45^{c}	39.36^{c}	38.74^{c}	39.05^{c}
30	14.99^{b}	14.94^{b}	14.97^{b}	44.04^{b}	45.11^{b}	44.58^{b}
40	17.29^{a}	17.33^{a}	17.31^{a}	49.79^{a}	51.13^{a}	50.46^{a}
SE ±	**0.094**	**0.090**	**0.023**	**0.178**	**0.231**	**0.146**
Level of Significance	*	*	*	*	*	*
Interaction						
N X Spacing	*	*	*	*	*	*

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

Number of Leaves

Application of 120 kg N ha^{-1} recorded more number of leaves than the remaining treatments at all the growth stages in both seasons (Table 3). This was followed by 90 kg N ha^{-1}. And the Least mean value was obtained in 0 kg N ha$^{-1.}$

The number of leaves differed significantly with response to inter row spacing. Plant sown at 40 cm inter row spacing recorded more number of leaves than 30 and 20 cm row spacing. This was followed by 30 cm inter row spacing which is higher than 20 cm row spacing.

Table 3: Mean Number of Leaves 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	7.79^{e}	7.82^{e}	7.81^{e}	13.28^{e}	14.73^{d}	14.01^{e}
30	9.40^{d}	9.47^{d}	9.43^{d}	16.46^{d}	17.87^{c}	17.16^{d}
60	10.81^{c}	10.54^{c}	10.68^{c}	18.09^{c}	18.05^{c}	18.97^{c}
90	12.38^{b}	12.31^{b}	12.34^{b}	19.09^{b}	18.84^{b}	1897^{b}
120	13.32^{a}	13.23^{a}	13.28^{a}	21.33^{a}	20.31^{a}	20.82^{a}
SE ±	**0.131**	**0.213**	**0.125**	**0.192**	**0.298**	**0.131**
Level of Significance	*	*	*	*	*	*
Row Spacing (cm)						
20	9.77^{c}	9.73^{c}	9.75^{c}	16.53^{c}	16.22^{c}	16.38^{c}
30	10.81^{b}	10.93^{a}	10.87^{b}	17.30^{b}	17.97^{b}	17.64^{b}
40	11.63^{a}	11.36^{a}	11.50^{a}	19.11^{a}	19.69^{a}	19.40^{a}
SE ±	**0.101**	**0.165**	**0.097**	**0.149**	**0.137**	**0.101**
Level of Significance	*	*	*	*	*	*
Interaction						
N X Spacing	*	*	*	*	*	*

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 Stem Girth (mm)

There was significant difference between the stem girths of amaranthus with respect to nitrogen fertilizer (Table 4). Application of 120 kg N ha^{-1} produced plants with remarkably thicker stem girth than all other treatments, at all growth stages in both the two years of the experiment and the combined. This were followed by 90 kg N ha^{-1} , 60 kg N ha^{-1} , 30 kg N ha^{-1} and 0 kg N ha^{-1} , respectively.

Response to inter row spacing showed that the effect of the inter row spacing had similar pattern at all stages. The result showed that 40 cm inter row spacing produced plant with higher stem girth than the rest of the treatments. This was 30 cm row spacing. Inter row spacing of 20 cm produced plants with thinnest stem girths.

Table 4: Mean Stem Girth (mm^2) 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	3.48^e	3.52^e	3.50^e	7.04^e	7.36^e	7.20^e
30	5.23^d	5.37^d	5.30^d	8.52^d	9.03^d	8.78^d
60	6.98^c	7.01^c	6.99^c	10.03^c	9.22^c	9.63^c
90	7.50^b	7.51^b	7.50^b	11.29^b	10.16^b	10.72^b
120	8.12^a	8.08^a	8.10^a	12.20^a	11.33^a	11.77^a
SE ±	**0.058**	**0.054**	**0.040**	**0.114**	**0.044**	**0.061**
Level of Significance	*	*	*	*	*	*
Row Spacing (cm)						
20	5.77^c	5.85^c	5.81^c	9.34^c	8.60^c	8.97^c
30	6.25^b	6.30^b	6.27^b	9.77^b	9.35^b	9.56^b
40	6.76^a	7.74^a	6.75^a	10.35^a	10.31^a	10.33^a
SE ±	**0.045**	**0.042**	**0.031**	**0.088**	**0.034**	**0.047**
Level of Significance	*	*	*	*	*	*
Interaction						
N X Spacing	**NS**	**NS**	**NS**	**NS**	*	*

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

Leaf Area (mm^2)

The effect of nitrogen fertilizer on leaf area per plant was significant (Table 5). Application of 120 kg N ha-1 produced plants with remarkable higher leaf area than the rest of the treatment at all the growth stages in both years of the experiment and the combined. This was followed by 90 kg N ha-1. The least value was recorded in the application of 0 kg N ha-1. The result followed the same pattern in response to row spacing. There was increased in leaf area with increased in row spacing up to 40 cm.

Table 5: Mean Leaf Area (mm^2) 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	73.06[e]	79.88[e]	76.47[e]	593.51[e]	755.51[d]	674.51[e]
30	126.61[d]	137.12[d]	131.87[d]	1112.14[d]	1250.84[c]	1181.49[d]
60	236.51[c]	257.74[c]	247.13[c]	1464.24[c]	1233.96[c]	1349.10[c]
90	387.84[b]	401.22[b]	394.53[b]	1802.03[b]	1528.91[b]	1665.47[b]
120	653.73[a]	677.45[a]	665.59[a]	2944.26[a]	2362.47[a]	2653.37[a]
SE ±	**4.807**	**9.821**	**5.494**	**30.854**	**41.717**	**25.944**
Level of Significance	*	*	*	*	*	*
Row Spacing (cm)						
20	217.69[c]	227.48[c]	222.58[c]	1222.55[c]	981.07[c]	11o1.81[c]
30	272.33[b]	291.88[b]	282.10[b]	1526.01[b]	1313.84[b]	1419.93[b]
40	396.64[a]	412.69[a]	404.66[a]	2001.14[a]	1984.10[a]	1992.62[a]
SE ±	**3.724**	**7.608**	**0.057**	**23.900**	**32.314**	**20.096**
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

Leaf Area Index (LAI) ($plant^{-1}$)

The result of leaf area index per plant is presented in Table 6. The result showed a steady increase in LAI with increasing level of nitrogen fertilizer. At all the growth stages, in all the two years of the experiment and in the combined, application of 120 kg N ha-1 produced significantly higher LAI than all other treatments. These were followed by 90 kg N ha-1.The least value of LAI was recorded in treatments with 0 kg N ha-1.

Response of LAI to row spacing was also significant. Plants sown at inter row spacing of 20 cm recorded more LAI than plant sown at 30 and 40 cm inter row spacing, respectively. This is followed by 40 cm row spacing which recorded higher LAI than 30 cm row spacing.

Table 6: Mean Leaf Area Index 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	0.48^{e}	0.52^{e}	0.50^{e}	3.92^{e}	4.82^{d}	4.37^{e}
30	0.85^{d}	0.92^{d}	0.89^{d}	7.68^{d}	8.53^{c}	8.10^{d}
60	1.60^{c}	1.76^{c}	1.68^{c}	10.21^{c}	8.53^{c}	9.37^{c}
90	2.65^{b}	2.76^{b}	2.71^{b}	12.44^{b}	10.49^{b}	11.47^{b}
120	4.35^{a}	4.62^{a}	4.49^{a}	19.78^{a}	15.12^{a}	17.49^{a}
SE ±	**0.033**	**0.091**	**0.048**	**0,204**	**0.218**	**0.149**
Level of Significance	*	*	*	*	*	*
Row Spacing (cm)						
20	2.17^{a}	2.27^{a}	2.22^{a}	12.23^{a}	9.82^{a}	11.02^{a}
30	1.82^{c}	2.01^{b}	1.19^{c}	10.17^{b}	8.76^{b}	9.47^{c}
40	1.98^{b}	2.06^{b}	2.02^{b}	10.06^{b}	9.92^{a}	9,97^{b}
SE ±	**0.025**	**0.070**	**0.037**	**0.158**	**0.169**	**0.116**
Level of Significance	*	*	*	*	*	*
Interaction						
N X Spacing	*	*	*	*	*	*

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

Absolute Crop Growth Rate (ACGR) (g wk3) Per Plant

The result of absolute crop growth rate (ACGR) at 6 WAS for 2012, 2013 and combined, recorded a significantly higher effects (Table 7). Application of 120 kg N ha-1 recorded more absolute crop growth rate (ACGR per plant. These were followed by 90 kg N ha-1 which was at par to the rest of the treatments.

The row spacing of 40 cm recorded significantly higher ACGR per plant compared to 30 and 20 cm row spacing, respectively.

Table 7: Mean Absolute Crop Growth Rate (ACGR) (g wk^{-3}) Per Plant 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	0.14^{e}	0.14^{e}	0.14^{e}
30	0.22^{d}	0.22^{d}	0.22^{d}
60	0.26^{c}	0.25^{c}	0.26^{c}
90	0.32^{b}	0.31^{b}	0.32^{b}
120	0.46^{a}	0.36^{a}	0.41^{a}
SE ±	**0.004**	**0.004**	**0.003**
Level of Significance	*	*	*
Row Spacing (cm)			
20	0.21^{c}	0.21^{c}	0.21^{c}
30	0.28^{b}	0.27^{b}	0.27^{b}
40	0.35^{a}	0.29^{a}	0.32^{a}
SE ±	**0.003**	**0.003**	**0.002**
Level of Significance	*	*	*
Interaction			
N X Spacing	*	*	*

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

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 8. The result showed that harvestable fresh yield of vegetable amaranth was positively and strongly correlated to plant height, number of leaves, stem girth, leaf area, leaf area index, 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; as leaf area index and number of leaves are directly related. Leaf area index increased significantly as row spacing decreased and N fertilizer rate increased.

Table 8: Matrix of correlation showing the associations among vegetative characters, in the combined season's of 2012 and 2013.

	PH	*NL*	*SG*	*LA*	*LAI*	*ACGR*
PH	1.0000					
NL	0.71270**	1.0000				
SG	0.66542**	0.83662**	1.0000			
LA	0.78374**	0.83176**	0.91360**	1.0000		
LAI	0.65631**	0.93990**	0.92261**	0.88004**	1.0000	
ACGR	0.69468**	0.82297**	0.81880**	0.87987**	0.82102**	1.0000

PH = Plant height
NL = Number of leaves
SG = Stem girth
LA = Leaf area
LAI = Leaf area index
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 growth parameters. There was linear increased in all the growth 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 growth rate in 2012 and 2013 (combined).

There was significant association between plant height and other growth components recorded in both years of the experiment and in the combined. Rate of growth were least in plants without the application of N fertilizer in both cropping season.

Significantly higher plant height and number of leaves 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 in Northern Guinea Savannah zone of Nigeria.

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 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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