Falodun EJ and Edafe VE (2020)
Notulae Scientia Biologicae 12(3):719-728
DOI:10.15835/nsb12310754
Research Article

Productivity, nutrient concentration, uptake and quality of Amaranthus (*Amaranthus cruentus* L.) as influenced by cutting heights and fertilizer type

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Abstract

Amaranthus cruentus L. is a leafy vegetable that is cultivated mainly for its leaves and grains. Due to high demand for this crop in Nigeria, the need to boost its productivity becomes necessary. Field and laboratory studies were conducted during in two successive cropping seasons at the experimental farm and laboratory unit of the Department of Crop Science, Faculty of Agriculture, University of Benin, Benin City. Three cutting heights C1: (10 cm), C2: (15 cm), C3: (20 cm) and a control C0: (no cutting) and four rates of fertilizer application F0: (Control), F1: (10 t ha^{-1} poultry manure), F2: (150 kg ha^{-1} NPK15:15:15) and F3 (75 t ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure) constituted the treatments. The treatments were in three replicate laid out in a (4 × 4) factorial arrangement in a randomized complete block design. Data collected were plant height (cm), leaf area (cm^2), stem diameter (cm) and number of branches. Fresh and dry herbage yield were taken at harvest. Growth, yield, and quality of *Amarathus cruentus* were significantly influenced by cutting heights and fertilizer application. In both years, number of branches (3.50 and 6.01) were lowest at C0 compared with other treatments. Herbage fresh and dry yield (49.10 t ha^{-1} and 18.20 t ha^{-1}) were highest at C3 and was consistent in both years. Similarly, the concentration of K, Ca, and Mg in plant tissue and the uptake of nutrients (N, P, K, Ca, Mg, and Na) increase at C3 compared with other treatments. F3 significantly ($p<0.05$) produced highest dry herbage yield (13.08 t ha^{-1}and 25.15 t ha^{-1}) in both years. Crude protein, fibre and fat content of the shoots were highest at cutting height of C3 and at F3 fertilizer rate. Therefore, for good yield and better quality of *Amaranthus cruentus* L, a combination of (75 t ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure) at cutting height of C3: (20 cm above soil level) is recommended for *Amaranthus cruentus* L production in the study area.

Keywords: herbage yield; nutrient uptake; plant tissue; vegetables

Introduction

Amaranthus cruentus L. commonly known as Amaranth belongs to the family Amaranthaceae. It is a dual-purpose crop, grown both for its leaves and grains. *A. cruentus* is a vegetable of high dietary value produced and consumed in most parts of Nigeria. Nutritionally, the leaves are rich in protein, vitamin A and potassium (Tindall, 1986; Akanbi and Togun, 2002). The leaves are being processed into many food items, supplements,

Received: 13 Jun 2020. Received in revised form: 13 Aug 2020. Accepted: 25 Sep 2020. Published online: 29 Sep 2020.

and additives (NIHORT, 1986; Ojo and Olufolaji, 1987). Despite the popularity of this vegetable in traditional cropping system, the production and nutritional values of these vegetables are limited due to poor agronomic practices and low fertility of native soils in most parts of Nigeria (Law-Ogbomo *et al.*, 2012). Efforts to develop and use fertilizer that will boost agricultural production and at the same time be friendly to the environment need be encouraged. The use of animal residues such as poultry manure for the growth and yield of vegetable and other crops had been advocated because of their low cost and availability (Moyin-Jesu, 2002). A continual dependence on chemical fertilizers may be accompanied by a fall in organic matter content, increased soil acidity, degradation of soil physical properties and increased rate of erosion due to instability of soil aggregates (Adeoluwa and Akinyemi, 2014). One of the ways to maintain or improve the soil fertility is by maintaining its organic matter. Vegetable farmers mostly apply poultry manure in combination with inorganic nitrogen-based fertilizers such as urea and NPK often because poultry manure alone is believed to dissolve slowly and may not meet up the yield of vegetables. The combine use of organic or inorganic fertilizers can give the desired higher sustainable crop yields than sole use of organic or inorganic fertilizer (Adeoye *et al.*, 2008; Akanbi *et al.*, 2010; Gundlade *et al.*, 2011). Falodun *et al.* (2013) reported that complimentary use of organic fertilizers can give the desired higher sustainable crop yields than sole use of inorganic fertilizer. Amaranth, like other leaf vegetables can be harvested either by uprooting (NIHORT, 1986) or repeated cutting back of the shoots until when inflorescences appear on the main trunks. Repeated cutting when done at adequate height and interval was observed to produce higher shoot yield of *Corchorus* sp. per unit of land (NIHORT, 1986). Stem cuttings at several intervals above the ground permit the lateral shoots to grow so that harvesting can be done a greater number of times. This is more economical and produces higher returns when compared with the situation in which the plants were uprooted once. Spreading of harvest over time also stabilizes produce, market price and hence higher returns. Mnzava and Masam (1985) reported that leaf yield depends on the portion of leaves and buds left behind for re-growth. They also found 20 cm initial cutting height as most suitable for *A. cruentus* compared to 3, 10 and 15 cm. These results therefore clearly show that less destructive cutting heights were beneficial for amaranth species probably due to more leaf and buds remaining on the stem consequently resulting in a high level of auxin for re-growth. The objective of this study is to determine the effect of cutting height and fertilizer type on productivity, nutrient concentration, uptake, and quality of *Amaranthus cruentus* (L).

Materials and Methods

Experimental site and soil properties

The field experiment was conducted for two consecutive crop cycles (2017- 2019) at the Experimental Farm of the Department of Crop Science, Faculty of Agriculture, University of Benin, Benin City, Nigeria. The location lies between latitude 6° 14' N and 7° 34' N and longitude 5° 40' E and 6° 43' E on elevation of 162 m above sea level. The monthly rainfall distribution pattern for the area is bimodal with peaks in June and September. Annual rainfall ranges from 1200 to 1450 mm spanning over eight months (March to October) with a dry spell in August. The dry season is from November to March. Prior to laying out of the experiment, composite soil samples collected at a depth of 0 - 5 cm from the top soil were air-dried, sieved, and packaged for routine soil physicochemical analysis. Soil pH was determined using a pH meter. Organic carbon was determined by wet oxidation method (Walkley and Black, 1962) as modified by Jackson (1969). Total nitrogen was obtained by macro Kjeldahl method as modified by Jackson (1969). Available P was extracted by Bray I method (Bray and Kurtz, 1945) and P was estimated by the blue colour method of Murphy and Riley (1962). Exchangeable K and Na were determined using flame photometer, while Ca and Mg were determined using the Atomic Absorption Spectrophotometer. The results of the soil analysis and swine manure are presented in collected at a depth of 0 - 15 cm from the top soil were air – dried, sieved and subjected to routine soil analysis using standard laboratory procedures (Table1).

Table 1. Physico-chemical composition of soil from experimental site pre planting

pH (H_2O)	5.65
Phosphorus (mg kg^{-1})	6.02
Total Nitrogen (%)	0.03
Exchangeable bases (cmol kg^{-1})	
Calcium	0.65
Magnesium	0.20
Potassium	0.12
Sodium	0.13
Organic matter (%)	17.12
Sand (%)	89.20
Silt (%)	5.30
Clay (%)	5.50
Textural class	Sandy loam

Source of planting material

A. cruentus seeds and poultry manure used for the experiment were obtained from the Department of Crop Science Farm and Animal Science Farm Unit of University of Benin respectively, while NPK 15:15:15 fertilizer was obtained from Agricultural Development Programme (ADP), Edo State, Nigeria.

Experimental design

Raised beds 1 x 1 m with a boundary of 0.5 m were manually prepared and laid out in a 4 × 4 factorial arrangement fitted into a randomised complete block design (RCBD) with 16 treatments replicated 3 times. The treatments were based on four cutting heights C0: (no cutting), C1: (10 cm), C2: (15 cm), C3:(20 cm) and four rates of fertilizer application F0: (Control), F1: (10 t ha^{-1} poultry manure), F2: (150 kg ha^{-1} NPK15:15:15) and F3: (75 kg ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure). The poultry manure used for the experiment was incorporated into their respective plots, depending on the treatment, and left for two weeks before transplanting of seedlings for equilibration. Seeds of *A. cruentus* were sown through broadcasting in the nursery and transplanted to the field when seedlings were three weeks after sowing (WAS) at one seedling per stand at a spacing of 20 x 20 cm giving a plant population of 250,000 plants ha^{-1}. Plots were mulched to conserve soil moisture; weeding was done first at two weeks after transplanting and subsequently weeding was done as soon as weeds emerged.

Sampling and measurement

Data collection started four weeks after transplanting (WAT) and continued fortnightly thereafter. Four plants were randomly selected from each plot and tagged for the purpose of collecting data for plant height (cm), number of leaves, number of branches, leaf area (cm) and stem diameter (cm). Harvesting of plants was by cutting the plants at 10, 15 and 20cm above soil surface as per treatment. This was repeated fortnightly until when inflorescence appeared at (10 WAT) on the non-cut plants or on the side shoots of the cut plants. A total of four cuttings were made. The cumulative herbage fresh yield was determined at the end of the last harvest for all the treatment except for the non-cut plant treatment in which shoot harvesting was done once at 10 weeks after sowing and used to estimate its herbage fresh yield in (t ha^{-1}) based on the formula below

$$Yield\ (tonnes\ \text{per hectare}) \quad = \quad \frac{Plot\ yield\ (tonnes) x\ 10000}{Plot\ size\ (metre\ sq.)}$$

For dry herbage yield, fresh shoot samples were chopped and packed inside well labelled envelopes and dried in oven at 70 °C to attain a constant weight. This was done periodically (for the cut plants) and total dry herbage yield (for non – cut plants). The dried samples were there after weighed using a sensitive electronic balance and the weight recorded. The cumulative dry herbage yields were obtained by adding together individual value obtained at each harvest and estimated in (t ha $^{-1}$).

Determination of tissue nutrient concentration, uptake and proximate analysis of Amaranthus cruentus leaves

At 70 DAT (at harvest leaves were harvested, cleaned of soil particles with distilled water and air dried and weighed with a sensitive balance. The leaves were chopped into small bits and packed inside well labelled envelopes and oven dried in a forced-Air Sanyo Gallen kamp moisture extraction oven at 70 °C to a constant weight (ISTA, 1993). The dried samples were there after weighed using a sensitive electronic balance and the weight recorded. These were milled to pass through 0.2 mm sieve using Thomas Wiley Hammer Mill in preparation for laboratory analysis. Proximate composition was analysed using the AOAC (1990) method. The components of proximate composition are crude protein (CP), crude fiber (CF), and ether extract (EE), ash, moisture, and carbohydrate content. Calcium (Ca), Sodium (Na) and Magnesium (Mg) along with N, P and K were determined following standard laboratory procedures. The analytical procedures for the nutrients were as described by AOAC (2000). Nitrogen, P, K, Ca, Na and Mg uptakes were calculated using the formula:

Nutrient uptake = oven dry weight of tissue x nutrient content in plant tissue (%).

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA), using SAS (Statistical Analysis Software) and least significance difference (LSD) test at 5% level of probability was used to compare the significant treatment mean.

Results

The chemical characteristics of the soil used for the experiment showed that the soil was strongly acidic and low in the essential soil nutrients (Table1). Significant $P \leq 0.05$ differences were observed in some of the agronomic parameters measured as influenced by cutting heights and fertilizer application. In 2017/18, irrespective of the cutting height, plants that were cut produced significantly similar and higher number of leaves and branches compared to the non-cut plants. The number of leaves increased from (36.34 to 67.41) for the cut plants and number of branches (3.50) was lowest with the non-cut plants and increased to (7.24) when plants were cut at C3 while the leaf area (32.29 cm ^{2}) was highest at C0 (the non - cut plants) and increased significantly above plants that were cut. In 2018/19, the number of leaves (80.53) was highest at C2 (plants cut at 15 cm above soil level) while the stem diameter (0.45) was least with plants that were not cut (Table 2). Similarly, plants that received fertilizers produced significantly higher number of leaves and stem diameter compared with the non-fertilize plants in both years. In 2017/18 season there were significant differences in all the yield characters measured, C3 (plants cut at 20 cm above soil surface) significantly $P \leq 0.05$ produced higher fresh herbage weight per plant (20.42 g), fresh and dry herbage yield (49.10 and 18.20 t ha $^{-1}$) above other cutting heights (Table 2). In 2018/2019, irrespective of cutting height, plants cut at 10 cm (C1), 15 cm (C2) and (C3) 20 cm were similar and enhanced fresh herbage weight per plant (32.54, 26.12 and 20.27 g) and fresh herbage yield (67.10, 57.41 and 48.40 t ha $^{-1}$) compared with the non-cut plants (C0) which significantly produced the lowest values of 15.39 g and 37.00 t ha $^{-1}$ respectively for these parameters. Plants cut at 20 cm above soil level (C3), consistently produced the highest fresh and dry herbage yield in both years. Amaranths plants performed better with application of fertilizer compared to non- fertilized plants, fertilizer application had a significant ($P \leq 0.05$) effect on the yield attributes. The dry herbage yield increased from 9.21 to 15.99 and 18.92 and 25.15 t ha $^{-1}$ when (F2) and (F3) fertilizer rates were used respectively. In 2017/18, application of F2 and F3 significantly ($p<0.05$) produced similar highest dry herbage yield of (15.99 and 13.08 t ha $^{-1}$) respectively. However, F3 consistently produced the highest dry herbage yield (13.08 and 25.15) in both years (Table 2).

Cutting height increased nutrient concentration of K from (0.27 to 0.44 g g^{-1}), Mg (0.37 to 0.63 g g^{-1}) and Ca (2.10 and 3.32 g g^{-1}) while N, K and Ca concentrations were increased with fertilizer applied as sole inorganic (F2) or combination of organic and inorganic fertilizer (F3) (Table 3). Nutrient uptake increased with increase in cutting height. Uptakes (Kg ha^{-1}) of N (1.67), P (41.01), K (24.08), Ca (180.58) and Na (0.35) were highest at (C3) plants cut at 20 cm above soil level (Table 4). Similarly, plants that received fertilizers increased nutrient uptake above the non - fertilized plants. The moisture content on dry matter basis (3.50%) was highest at cutting height of 15 cm above ground level while the ash (5.70%) and percentage crude protein content (5.03%), fat (7.92%) and fibre (6.22%) increased with increase in cutting height and was highest at (C3) cutting at 20 cm above ground. Moisture contents (3.00 and 3.00%) were similar and higher in F0 (no fertilizer application) and F1 (10 t ha^{-1} sole poultry manure application) (Table 5). The percentage ash and crude protein content (5.40 and 4.26%) were highest at F2 and F3 respectively and lowest at F0 (4.12 and 1.84%). Carbohydrate content decreased with increase in cutting height and fertilizer application and was highest at C0 (83.93%) and F0 (81.46%). The use of F3 (75 kg ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure), increased the crude fat (6.70%) and fibre content (4.62%) of amaranths leaves above other treatments (Table 6).

Table 2. Effect of cutting height and fertilizer application on some vegetative characters of *Amaranthus cruentus* L.

Treatment	2017/2018 Cropping season					2018/2019 Cropping season				
	Plant height (cm)	Number of leaves	Number of branches	Leaf area (cm^3)	Stem diameter (cm)	Plant height (cm)	Number of leaves	Number of branches	Leaf area (cm^3)	Stem diameter (cm)
Cutting height (cm)										
C 0	45.79a	36.34b	3.50b	32.29a	2.52a	21.61b	48.05c	6.01b	22.20a	0.45b
C 1	38.99a	42.62a	5.65a	18.44b	2.27ab	36.19a	45.15c	10.15a	17.27a	0.99a
C 2	37.26a	48.66a	6.90a	16.61b	2.05a	44.28a	80.53a	13.27a	25.03a	1.30a
C 3	39.63a	67.41a	7.24a	16.83b	2.31ab	45.17a	59.44b	10.83a	28.40a	1.21a
Significance	Ns	*	*	*	*	*	*	*	Ns	*
Lsd $_{(0.05)}$	13.22	7.79	2.08	6.68	0.31	10.20	4.67	3.31	31.06	0.35
Fertilizer rates										
F 0	42.01a	43 27b	7.81a	18.68a	2.20a	34.31a	47 52b	9.17a	47.22a	0.79b
F 1	42.20a	57.42a	8.30a	23.81a	2.25a	40.02a	60.21a	9.90a	57.23a	1.17a
F 2	32.58a	56.18a	8.54a	19.08a	2.44a	36.11a	67.14a	11.65a	50.43a	1.11a
F 3	34.99a	57.50a	8.60a	17.63a	2.25a	38.12a	66.18a	12.21a	52.15a	1.15a
Significance	Ns	*	Ns	Ns	Ns	ns	*	ns	ns	*
Lsd $_{(0.05)}$	13.22	7.79	2.08	6.58	0.31	10.20	4.67	3.31	31.06	0.35
Interaction										
C*F	Ns	Ns	Ns	Ns	Ns	ns	Ns	ns	ns	ns

Means followed by the same alphabets along rows are not significantly different at 5% level of probability

C0: No cutting, C1: (10 cm), C2: (15 cm), C3: (20 cm) above soil level.

F0: Control, F1: 10 t ha^{-1} poultry manure, F2: 150 kg ha^{-1} NPK 15:15:15, F3: 75 kg ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure.

Table 3. Effect of cutting height and fertilizer application on herbage yield of *Amaranthus cruentus* L.

Treatment	2017/2018 Cropping season			2018/2019 Cropping season		
	Fresh herbage wt (g/plt)	Fresh herbage yield (t ha^{-1})	Dry herbage yield (t ha^{-1})	Fresh herbage wt (g/plt)	Fresh herbage yield (t ha^{-1})	Dry herbage yield (t ha^{-1})
Cutting height						
C 0	15.35b	35.60b	11.50c	15.39b	37.00b	13.44d
C 1	16.84b	34.80b	14.20b	32.54a	67.10a	29.31c
C 2	16 77b	35.00b	14.10b	26.12a	57.41a	25.53b

C 3	20 42a	49.10a	18.20a	20.27a	48.40a	28.32a
Significance	*	*	*	*	*	*
Lsd $_{(0.05)}$	2.13	10.52	3.50	10.32	3.14	2.19
Fertilizer rates						
F 0	18.92b	28.50c	9.21b	28.99a	47.42b	18.92c
F 1	24.88a	35.90bc	11.59b	37.34a	56.22a	22 41b
F 2	24.12a	49.50a	15.99a	36.10a	53.45a	21.20b
F 3	25.16a	40.50ab	13.08a	36.25a	54.82a	25.15a
Significance	*	*	*	ns	*	*
Lsd $_{(0.05)}$	2.13	10.52	3.50	10.32	3.14	2.19
Interaction						
C*F	ns	Ns	ns	ns	ns	Ns

Means followed by the same alphabets along rows are not significantly different at 5% level of probability
C0: No cutting, C1: (10 cm), C2: (15 cm), C3: (20 cm) above soil level.
F0: Control, F1: 10 t ha^{-1} poultry manure, F2: 150 kg ha^{-1} NPK 15:15:15, F3: 75 kg ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure.

Table 4. Effect of cutting heights and fertilizer applications on nutrient concentration of *Amaranthus cruentus* L.

	Nutrient concentration (g kg $^{-1}$)					
Treatment	N	P	K	Mg	Ca	Na
Cutting height						
C0	0.01b	0.42a	0.27b	0.37b	2.10b	0.01a
C1	0.01b	0.41a	0.25b	0.32b	1.94b	0.01a
C2	0.01b	0.48a	0.31b	0.46b	2.47b	0.20a
C3	0.03a	8.39a	0.44a	0.63a	3.32a	0.01a
Significance	*	ns	*	*	*	ns
LSD $_{0.05}$	0.01	0.07	0.09	0.15	0.73	0.29
Fertilizer rate						
F0	0.01b	0.36a	0.20b	0.37a	1.09b	0.01a
F1	0.01b	0.51a	0.33a	0.48a	2.76a	0.01a
F2	0.03a	8.32a	0.36a	0.52a	2.66a	0.21a
F3	0.02ab	0.51a	0.33ab	0.41a	2.51a	0.01a
Significance	*	ns	*	ns	*	ns
LSD $_{0.05}$	0.01	0.07	0.09	0.15	0.73	0.29

Means followed by the same alphabets along rows are not significantly different at 5% level of probability
C0: No cutting, C1: (10 cm), C2: (15 cm), C3: (20 cm) above soil level.
F0: Control, F1: 10 t ha^{-1} poultry manure, F2: 150 kg ha^{-1} NPK 15:15:15, F3: 75 kg ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure.

Table 5. Effect of cutting heights and fertilizer applications of nutrient uptake of *Amaranthus cruentus* L.

	Nutrient uptake (kg ha^{-1})					
Treatments	N	P	K	Mg	Ca	Na
Cutting height						
C0	0.68d	29.58c	14.30d	19.85c	152.25d	0.06d
C1	0.85c	33.90b	19.00c	24.84b	156.33c	0.14c
C2	1.17b	33.65b	21.89b	34.91a	172.75b	0.19b
C3	1.67a	41.01a	24.08a	34.45a	180.58a	0.35a
Significance	*	*	*	*	*	*
LSD $_{0.05}$	0.08	1.57	1.15	1.82	3.86	0.02
Fertilizer rate						
F0	0.93c	32.69b	18.35c	26.80b	160.16b	0.13c
F1	1.07b	34.44a	19.10bc	28.29ab	166.33a	0.19b
F2	1.19a	35.30a	20.16b	29.08a	168.58a	0.20ab
F3	1.18a	35.73a	21.65a	29.89a	166.83a	0.22a
Significance	*	*	*	*	*	*
LSD $_{0.05}$	0.08	1.57	1.15	1.82	3.86	0.22

Means followed by the same alphabets along rows are not significantly different at 5% level of probability
C0: No cutting, C1: (10 cm), C2: (15 cm), C3: (20 cm) above soil level.
F0: Control, F1: 10 t ha^{-1} poultry manure, F2: 150 kg ha^{-1} NPK 15:15:15, F3: 75 kg ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure.

Table 6. Effect of cutting heights and fertilizer application on moisture, ash, and crude protein contents *Amaranthus cruentus* L.

Treatments	Moisture (% dry matter content)	Ash content (%)	Crude protein content (%)
Cutting height			
C0	3.25b	4.30d	1.09d
C1	2.25c	4.82c	2.28c
C2	3.50a	5.05b	4.87b
C3	2.00d	5.70a	5.03a
Significance	*	*	*
Fertilizer rate			
F0	3.00a	4.12d	1.84d
F1	3.00a	5.07c	3.06c
F2F	2.50b	5.40a	3.60d
F3	2.50b	5.27b	4.26a
Significance	*	*	*

Means followed by the same alphabets along rows are not significantly different at 5% level of probability
C0: No cutting, C1: (10 cm), C2: (15 cm), C3: (20 cm) above soil level.
F0: Control, F1: 10 t ha^{-1} poultry manure, F2: 150 kg ha^{-1} NPK 15:15:15, F3: 75 kg ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure.

Table 7. Effect of cutting heights and fertilizer application on fat, crude fibre and carbohydrate content of *Amaranthus cruentus* L.

Treatments	Crude fat content (%)	Crude fiber content (%)	Carbohydrate content (%)
Cutting height			
C0	4.72d	2.80d	83.93a
C1	5.50c	3.80c	81.08b
C2	6.52b	3.97b	75.25c
C3	7.92a	6.22a	75.03d
Significance	*	*	*

Fertilizers rate			
F0	5.70d	3.85c	81.46a
F1	5.95c	4.52b	77.84b
F2	6.32b	3.80d	77.06c
F3	6.70a	4.62a	77.01d
Significance	*	*	*

Means followed by the same alphabets along rows are not significantly different at 5% level of probability
C0: No cutting, C1: (10 cm), C2: (15 cm), C3: (20 cm) above soil level.
F0: Control, F1: 10 t ha^{-1} poultry manure, F2: 150 kg ha^{-1} NPK 15:15:15, F3: 75 kg ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure.

Discussion

The soil used for this experiment was below the critical concentration level N (0.15%), P (8-10 mg kg^{-1}), K (0.20 cmol kg^{-1}), Ca (2.00 cmol kg^{-1}), Mg (0.26 cmol kg^{-1}) needed for arable crop production Agboola and Ayodele (1985). Hence the need for additional soil nutrients to increase the soil fertility. The increase in the vegetative characters especially in the number of leaves and branches as a result of cutting heights compared with the non-cut could probably be due to the fact that cut plants produced more leaves and buds on the stem consequently resulting in a high level of auxin for re-growth. Olufolaji and Tayo (1989) showed that the reaping and regrowth system of vegetable production was superior to a once only total harvest for Amaranthus (*Amaranthus cruentus* L.). They showed that the total numbers of leaves and branches of Amaranthus were greater, gaining a higher total fresh weight yield, and the total dry weight of various plant parts.

Stem cuttings at several intervals above the ground permit the lateral shoots to grow so that harvesting can be done a greater number of times. This work agrees with the findings of Akanbi *et.al.*, (2009) that cutting height has significant effect on the growth of amaranth. The significant lower number of leaves, stem diameter and yield attributes observed with the non-fertilized plants support the findings of Ojo and Olufolaji (1987) who reported that soils that are inherently low in essential nutrients, reduce the uptake and other physiological processes that cumulate into biomass production. This might be the reasons for observed low dry matter and shoot yield production for plants that were not fertilized. The significant increase in both fresh and dry herbage yield of *A. cruentus* with plants cut at 20 cm above ground level might be due to accumulation of higher nutrients and presence of more functional nodes from which side shoot re – growth occured. Hence better dry matter and shoot yield production of this cutting height over other cutting heights. These findings corroborate the work of Akanbi (2009) and Robert and Andrew (1989) who stated that repeated cutting of shoot produced higher shoot yield than harvesting once. Maruo *et al.* (2003) and Takagaki *et al.* (2003) reported that reaping and regrowth system is feasible for vegetable production especially leafy and shoot type vegetable. The increase in fresh and dry herbage yield observed with F2, (150 kg ha^{-1} NPK15:15:15) and F3, (75 kg ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure) could be attributed to its higher nutrient concentrations (N, P, K, Ca, Mg and Na), which increased the availability of nutrients in the soil, leading to increased uptake by *A. cruentus* plants. Thus, enhanced nutrition and increased number of functional nodes which had positive effects on the dry matter production and shoot yield). The higher concentration of N, P, K and Mg in C3: (plants cut at 20 cm above ground level) might be due to the fact that the plants absorbed more nutrient from the soil and the absorbed nutrients might have translocated to the new leaves that were formed. Ojeniyi and Odedina (2014) classified NPK and Mg as mobile plant nutrients while Fe, Mn and Ca were classified as immobile nutrients. Nutrient uptake for fertilizer rates revealed that plants that received fertilizer had more nutrient concentration than non-fertilized plants. This corroborates the findings of Ademola *et al.* (2019), who stated the significant increase in nutrient concentration as influenced by application of different fertilizer materials. The proximate composition values obtained in this study are slightly higher than those of Karuki *et al.* (2013) except for the crude protein. The increase in ash, crude protein, fat and crude fibre content of the shoot with increase in cutting height (especially in C3) and at F3 is an evident of an increase in the nutritional quality of *A cruentus*. This might be as a result of migration of nutrients to the newly formed shoots that were harvested.

Conclusions

This research work showed that cutting heights enhanced the growth, fresh herbage and dry herbage yield of *A. cruentus*. Sole application (F1) of 150 kg ha^{-1} NPK 15:15:15 produced the highest ash content while the non – cut plants produced the highest carbohydrate content. Plants cut at 20 cm above soil level produced the highest cumulative yield, nutrient uptake, fat content, crude fibre content and protein content of *A. cruentus*. These positive effects were more pronounced when the plants were cut at C3 (20 cm above soil level) and cropped with (F3). Cropping Amaranth with a combined application of fertilizer at 75 kg ha^{-1} NPK 15:15:15 + 5 t ha^{-1} poultry manure and subsequent harvesting cut at 20 cm above soil level are thereby suggested for Amaranth farmers.

Authors' Contributions

This work was carried out in collaboration between the authors. EJF designed the study, wrote the protocol, and wrote the first draft of the manuscript. EVE managed the literature search and experimental process. Both authors read and approved the final manuscript.

Acknowledgements

Authors are grateful to the University of Benin, Nigeria for the enabling environment to carry out this research and to Dr S.A. Ogedegbe for data analysis.

Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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