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Research Article
Effect of Ratooning on Growth and Nutritional Quality of *Amaranthus* (*Amaranthus tricolor*) in Alfisol South Western Nigeria

[1]Ayeni Leye Samuel, [2]Oyebamiji, Kehinde Johnson, [2]Morakinyo-Fasipe Olutoye Temitope and [3]Agbona Ademola Isaac

[1]Department of Agricultural Science, Adeyemi College of Education, Ondo, Nigeria
[2]Department of Crop Science, College of Agricultural Science, Ayo Babalola University, Arakeji, Ikeji, Osun State, Nigeria
[3]Department of Agricultural Technology, Federal Polytechnic, Ile Oluji, Ondo State, Nigeria

Abstract

Background and Objective: Increase in human population that results in food scarcity and malnutrition necessitates the need to increase growing of vegetable that is early maturing with well ratooning capacity. This study aimed to examine the effect of ratooning on growth, yield and nutrient uptake of *Amaranthus tricolor*. **Materials and Methods:** Two field experiments were conducted in 2017 at 2 different locations in Okegun situated at Ondo and Adeyemi College of Education Ondo, Teaching and Research Farm Ondo, South Western Nigeria. The treatments were harvesting by uprooting the plant or total harvesting of the plant at once (1 time harvest), twice (2 times harvest) and thrice (3 times harvest). The treatments were arranged in Randomized Complete Block Designed (RCBD) with three replications. The mean data for the two experiments were generated and used to discuss the findings. **Results:** Relative to total harvest, 2 and 3 times harvests significantly increased ($p<0.05$) plant height, fresh weight, dry weight, number of leaves and moisture content. Compared to total harvesting, 3 times harvest of *Amaranthus tricolor* increased plant height, number of leaves, fresh weight, dry weight and moisture content. Three times harvests recorded highest K. Two times harvest had highest Ca, Mg, Na, N and P. One time harvest significantly ($p<0.05$) recorded the highest Mn, Fe, Cu and Zn. Relative to 1 time harvest, 2 times harvest recorded highest increase in crude protein and fat content of *Amaranthus tricolor*. **Conclusion:** This study reported that the 3 times harvest recorded the highest growth parameters while 2 times harvest recorded the highest nutritional value of Amaranth in this experiment.

Key word: Agronomic parameters, amaranth, ratooning, crude protein, malnutrition, uprooting

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Corresponding Author: Ayeni Leye Samuel, Department of Agricultural Science, Adeyemi College of Education, P.M.B. 520, Ondo, Ondo State, Nigeria

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Vegetables are succulent crops that have the tendency of re-growth if harvested when they are still at their tender stage of development. According to Prasanna and Pattar[1] ratooning is common with crops like banana, red gram, cotton, Jowar, sugarcane but it has also been extended to vegetables like Amaranths. The ultimate aim of a farmer is to obtain optimum yield. African diets among the rural dwellers are mainly carbohydrates; hence, they need supplements[2]. Chadha *et al*.[3] observed that African leafy vegetables could make a positive contribution to world food security. The optimum yield of crops depends on the fertility of the soil, pests and diseases, cultural practices, season of planting, time and method of harvesting of such crop. Many farmers majorly focus on how to improve soil fertility and control pests and diseases with little emphasis on harvesting technique. Many research works have shown that harvesting has significant effect on growth, nutritional quality and yield of crops. Foidl *et al*.[4] conducted research on harvest frequency on the growth and leaf yield of moringa (*Moringa oleifera* lam), a leafy vegetable crop and obtain positive result. Ayub *et al*.[5] conducted an experiment on the effect of nitrogen application and harvesting intervals on forage yield and quality of pearl millet (*Pennisetum americanum* L.). Currently, there is a dearth of information on the growth performance, yield and nutritional quality of *A. cruentus*[6]. Different methods that are commonly used by the local farmers include total uprooting of the plant, cutting of the top of the plant to give room for side shoot development known as ratooning and tipping. Tipping is one of the methods used in harvesting *Amaranthus* and it is done by plucking off the growing points of the shoots, while cutting is done by first cutting the plants at a height not less than 15 cm, with sequential cutting of 5 cm above the previous cutting[7]. The increase in human population that results in food scarcity and malnutrition necessitates the need to increase growing of Amaranths that is early maturing with well ratooning capacity and good nutritive value. There is little or no known experiment that test the harvesting interval on nutritional quality of *Amaranthus tricolor* in Ondo, southwestern Nigeria. The objectives of this study were to compare the effect of total harvesting to partial harvesting on growth, nutrient uptake and nutritional quality of *Amaranthus tricolor* in Ondo south western Nigeria.

MATERIALS AND METHODS

Study area: The experiments were carried out at Okegun Farm in Ondo and the Teaching and Research Farm of Agricultural Science Department, Adeyemi College of Education, Ondo between August and October, 2017. Ondo is located in the latitude 70°, 05°N and longitude 40°, 55°E and at elevation of 381.3 m above the sea level. It belongs to the tropical rain forest zone. The soil belongs to the order Alfisol (U.S.D.A.) or Luvisol[8]. Evidence has shown that the land had been in use for planting various crops in the past. The lands were fairly flat, slightly sloppy and contained well drained loamy soil particles with small pebbles.

Soil sampling: Surface soil samples (0-20 cm) were randomly collected before the conduct of the experiment at the experimental sites, bulked, air-dried and sieved through 2 mm mesh. The bulked soil samples were analyzed for OM, total N, available P, K, Ca, Mg, Fe, Cu, Zn and Mn.

Experimental layout and design: The lands were manually cleared, stumped, mapped, pegged out and made into beds of 4 m by 4 m size with 0.5 m discard area. The experiments were laid out in Randomized Complete Block Design (RCBD) and replicated 3 times. The experimental treatments were total harvest (total uprooting-1 time harvest), 1st ratoon (2 times harvest) and 2nd ratoon (3 times harvest). The total harvest means that the tagged crops were uprooted and the roots were severed from the shoot exactly 28 days after sowing, 1st ratoon means that the tagged *Amaranthus tricolor* were partially cut at 28 days and finally uprooted at 42 days after sowing while the 2nd ratoon means that the tagged *Amaranthus tricolor* were partially harvested at 28 and 42 days and finally uprooted at 56 days after sowing. Ratoon in this context means, the shoots of the selected *Amaranthus tricolor* were harvested manually by cutting the stem with a local sharp knife at 20 cm above ground level and the remaining shoots of the plant were allowed to develop side shoots.

Planting of *Amaranthus* and cultural operation: *Amaranthus tricolor* seeds were purchased from the local market in Ondo. Sowing of seeds was done by broadcasting. The seeds were mixed with light dried soil to enhance even distribution of the seeds. The seeds were thinned to 20 stands per plot.

About 10 t ha^{-1} of fresh poultry manure was cured for 2 weeks and incorporated into all the plots 2 weeks before planting to improve the soil N, P and K content when the initial soil sample showed that the soils were deficient in N, P and K (Table 1). Weeding was done manually with hand-held hoe 2 weeks after planting.

Plant parameters determination: The parameters determined were plants height, number of leaves, number

of branches, leaf area, fresh weight, dry weight and moisture content. The N, P, K, Ca, Mg, Fe, Cu, Zn and Mn contents of the leaves were determined. Crude protein, fat, NFE, fibre and ash contents were also determined[9].

Five stands of amaranth were tagged per plot for data collection. The agronomic parameters determined were plant height, number of branches, number of leaves, leaf fresh and dry weight. Plant height was measured from the ground base of each tagged plant to the top using a meter rule. Number of leaves and branches were carried out by visual counting. The leaf area was determined using graphical method. Fresh weight was recorded by weighing the freshly harvested *Amaranthus tricolor* with weighing balance. The freshly harvested plants were oven dried and weighed with electric balance to determine the dry weight and moisture content of *Amaranthus tricolor*. For total harvest, *Amaranthus tricolor* was uprooted and the shoots were cut from the root at 28 days after sowing. For the 1st ratoon, (1 time harvest) the agronomic parameters determined at 28 and 42 days were added together to give cumulative yield while agronomic parameters determined at 28, 42 and 58 days were also summed up to give cumulative yield for the 2nd ratoon (2 times harvest).

The harvested plants from each plot were washed and transported in a well labeled envelope to the laboratory. The harvested plants were washed with distilled water and air-dried. The air-dried samples were packed inside well labeled envelopes and oven dried, at a low temperature until constant weights were recorded. The oven dried samples were allowed to cool inside a desiccator and grounded into powder. The grounded samples were then packed inside a cellophane nylon. The leaf N, P, K, Ca, Mg, Fe, Cu, Zn and Mn were analyzed from the wet digest of the leaf samples[9]. The nutritional quality such as crude protein, NFE, fibre and ash content were determined using AOAC[9] method. The nutrients uptake and nutritional quality of *Amaranthus tricolor* were determined at their final stages i.e., total harvest at 28 days, 1st ratoon at 42 days (1 time harvest) and 2nd ratoon at 58 days (2 times harvest) after sowing.

Statistical analysis: Data collected were subjected to one way analysis of variance using the Genstat software. The data collected from the two locations were combined and their means were used as result since the two locations had similar nutrient characteristics and belonged to the same group (Alfisol). Means were separated using Least Significant Difference at $p<0.05$ where F-ratio was significant.

RESULTS

The chemical characteristics of the soil used for the conduct of the experiment were presented in Table 1. The chemical properties of the soil showed that the soil were acidic, low in OM, N, P, K, Ca and Mg. The soil were high in Fe, Cu and Mn.

Effect of ratooning on agronomic parameters of *Amaranthus tricolor*: The effect of harvest at once, twice and thrice on growth parameters of *Amaranthus tricolor* was shown in Table 2. Compared to one time harvest, two times harvest and three times harvest significantly increased ($p<0.05$) plant height, number of leaves, number of branches, fresh and dry weight, moisture content and leaf area (except 2 times harvest).

The results showed that compared with 1 time harvest (total uprooting), plant height, number of leaves, fresh weight and moisture content of Amaranth were significantly increased ($p<0.05$). It was observed that 3 times harvest had the highest increase in all the agronomic parameters that were determined in this experiment.

Effect of ratooning on nutrient uptake of *Amaranthus tricolor*: Table 3 showed the result of ratooning on nutrient uptake of *Amaranthus tricolor*. Compared to one time harvest, two times harvest significantly increased ($p<0.05$) Ca, Mg, K and N while one time harvest recorded highest Mn, Fe, Cu and Zn.

Relative to 1 time harvest, *Amaranthus tricolor* harvested at 2 times recorded the highest increase in crude protein and crude fat (Table 4).

Table 1: Initial mean soil chemical properties of Okegun and Research Farm, Ondo

Soil properties	Values
pH	4.60
OM (%)	0.97
N (%)	0.04
P (mg kg^{-1})	5.79
Exchangeable bases (Cmol kg^{-1})	
K	0.08
Ca	0.67
Mg	0.81
Na	0.12
Micro nutrients (mg kg^{-1})	
Fe	23.40
Zn	4.86
Cu	8.70
Mn	7.19

Table 2: Cumulative effect of ratooning on growth and yield of *Amaranthus tricolor*

Treatments	Plant height (cm)	No. of leaves	No. of branches	Fresh weight/plant (g)	Dry weight/plant (g)	Moisture content	Leaf area (cm^2)
3 times harvest	48.77[a]	44.86[a]	4.44[a]	221.36[a]	46.56[a]	174.86[a]	18.04[a]
2 times harvest	35.21[b]	28.44[b]	4.11[a]	196.83[b]	23.30[b]	173.53[a]	8.26[b]
1 time harvest	22. 44[c]	11.99[c]	2.66[b]	37.00[c]	6.10[c]	30.90[b]	9.74[b]
Lsd (0.05)	4.56	7.67	1.21	10.34	10.00	10.12	3.89

Table 3: Cumulative effect of ratooning on nutrient uptake of *Amaranthus tricolor*

Treatments	Ca (%)	Mg (%)	K (%)	Na (%)	N (%)	P (%)	Mn (mg kg^{-1})	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})
3 times harvest	1.44[b]	1.09[b]	6.70[a]	1.15[a]	2.93[b]	0.39[a]	106.59[b]	403.56[c]	5.84[b]	54.09[c]
2 times harvest	1.90[a]	1.70[a]	6.24[a]	1.28[a]	3.69[a]	0.42[a]	115.26[b]	1283.45[b]	7.65[b]	66.89[b]
1time harvest	1.64[b]	1.07[b]	3.85[b]	0.83[b]	2.92[b]	0.39[a]	230.34[a]	4012.26[a]	61.43[a]	185.33[a]
Lsd (0.05)	0.27	0.12	1.34	0.27	1.11	NS	16.78	21.12	4.56	5.64

Table 4: Cumulative effect of ratooning on nutritional quality of *Amaranthus tricolor*

Treatments	Crude protein	Crude fat	NFE	Crude fibre	Ash
3 times harvest	11.90[b]	3.11[a]	40.02[a]	17.57[a]	9.11[a]
2 times harvest	19.56[a]	3.48[a]	41.35[a]	15.89[a]	9.00[a]
1 time harvest	16.79[b]	3.21[a]	45.15[a]	15.26[a]	8.67[a]
Lsd (0.05)	4.52	NS	NS	NS	NS

DISCUSSION

Agboola and Ayodele[10] recommended 3, 0.15%, 8-10 mg kg^{-1}, 0.2, 2.0 and 0.26 C mol kg^{-1} for OM, total N, available P, K, Ca and Mg, respectively as critical level of nutrients required for optimum production of arable crop in southwestern Nigeria. Going by Agboola and Ayodele[10] assertion, the chemical properties of the soils showed that the soils were acidic, low in OM, N, P, K, Ca and Mg; hence, additional soil nutrients were required to increase the fertility of the soil.

The result obtained in this research showed that harvesting interval affected the growth and yield of amaranths. This was in line with the work of Foidl *et al.*[4], who observed that average number of leaves of *Moringa oleifera* produced per plant increased with time in the experiment performed to show the effect of spacing and harvest frequency on growth and leaf yield of moringa (*Moringa oleifera* Lam), a leafy vegetable crop. Rambau *et al.*[11] also observed that stages of maturity had significant effects on leaf area and plant height in the experiment conducted to show the effect of three stages of maturity on the productivity, chemical composition and ruminant degradability of Napier grass *(Pennisetum purpureum).* The experiment conducted by Bashir *et al.*[12] to show the ratooning potential of different sugarcane genotypes at varying harvesting dates in Pakistan indicated that the growth and yield of cane varied significantly among all the harvesting dates examined.

The increase in the agronomic parameters in 2nd and 3rd time harvest in this experiment might be as a result of the nutrient absorbed by the plants more than the *Amaranthus tricolor* harvested at once. Three times harvest recorded the highest growth and yield parameters and was in line with the work of Ayeni *et al.*[13]. Though the cumulative agronomic parameters increased at highest harvest interval, yet there was reduction in nutritional quality of *Amaranthus* at 3rd time harvest. This might be partially adduced to senescence but might not be absolutely correct as the leaves harvested at the 3rd stage of harvest still remained green and fresh. Nouman *et al.*[14], also opined that cutting frequency and height significantly affected both fresh and dry vegetable biomass like moringa.

It was observed that the cumulative yield of the *Amaranthus tricolor* harvested at intervals were higher than *Amaranthus tricolor* harvested at once by uprooting. The better performance of *Amaranthus* harvested at different stages than the *Amaranthus* harvested at once might be as a result of the method of harvesting that gave room for the re-growth of the side shoots since all the plants were subjected to equal treatments in terms of soil fertility and cultural practices. Maboko and du Plooy [7] reported that harvesting amaranths by cutting resulted in a delay of plant maturity compared to tipping in an experiment conducted to show the effect of plant density and harvesting method on yield components of hydroponically grown amaranth. Ratooning might have caused the plants to absorb more nutrients from the soil. Also, the nutrients absorbed might have translocated to the new leaves that were formed. Ojeniyi and Odedina[15] and Conrad[16] classified N, P, K and Mg as mobile plant nutrients while Fe, Mn, Cu and Ca were classified as immobile plant nutrients. Based on the results obtained, the higher concentration of N, P, K and Mg in 2 and 3 times harvests (especially in 2 times harvest) might be as a result of migration

of these plant nutrients to the newly formed shoots. The higher concentration of the plant nutrients in the 2 and 3 times harvests might have increased the plant growth. The lower, protein, fat and NFE content in *Amaranthus tricolor* harvested three times interval showed the reduction in the nutritional quality of the crop. Ansah *et al.*[17] observed reduction in crude protein content of crops as harvesting intervals increased as equally observed in this work. Okubena-Dipeolu[18], Mabapa *et al.*[19] and Dev *et al.*[20] argued that nutritional quality of amaranths depends on certain conditions such as the nutrient status of the soil, soil type, type of fertilizer applied to the soil and harvesting period.

CONCLUSION

Experiments were conducted in Ondo southwestern Nigeria to determine the effect of ratooning on growth parameters, nutrient uptake and nutritional quality of *Amaranthus tricolor.* This research work ascertained that 3 times harvest had the highest cumulative growth and yield of *Amaranthus* tricolor while 2 times harvest recorded the highest crude protein.

SIGNIFICANCE STATEMENTS

There are different harvesting methods used in harvesting *Amaranthus* in southwest Nigeria. This study discovered that ratooning can increase the yield of amaranth up to 3 times harvest and that this can be beneficial for farmers who grow *Amaranthus* as means of livelihood. The study also shows that as the time of harvesting of amaranth increased, the level of crude protein and crude fat were reduced, thus, reducing the nutritional quality of the crop. This study will help the researchers to uncover the critical areas of *Amaranthus* that many researchers were not able to explore. Thus a new theory on improving the nutritional quality of *Amaranthus* at 3rd time harvest may be arrived at.

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