International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 26, No. 1, p. 1-7, 2025

RESEARCH PAPER

OPEN ACCESS

Vegetable yield of amaranthus as determined by repeated against uprooting harvesting

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Article published on January 03, 2025

Key words: Amaranthus yield, Repeated harvesting, Uprooting technique, Vegetable genotypes, Harvesting method

Abstract

Vegetable yield of Amaranthus is influenced as it would be expected by genetics, environment and management practices during the crop growth in the field, but also responds to harvesting technique once the crop has reached harvest. A study was conducted at Sokoine University of Agriculture in Morogoro, Tanzania, to evaluate yield performance of grain and vegetable type Amaranths under uprooting and repeated harvesting practices. Two vegetable type and one grain type Amaranths were used in the experiment, where harvesting involved clipping the growing shoot or twigs one quarter ($^1/_4$) or half ($^1/_2$) length of the shoot or twig from the lowest leaf node; or uprooting the plant from the soil then getting rid of the subterranean portion. Results from analysis of variance showed varying significant effects of harvesting techniques, varieties, and their interaction. Harvesting technique effects on yield were significant for the 1st, 2nd and 3rd harvest yields while effect of genotypes was significant throughout 1st to 5th harvests as well as total yield. Significant interaction existed in the 1st and total yields ($P \leq 0.05$). Repeated harvesting (clipping) increased total yield of the vegetable type genotypes over uprooting, while yield from uprooting was best in the grain type genotype, up to > 50% more yield. Differences in yield, one as high as 213.7% were observed between repeated harvesting and uprooting interacting with genotypes. Even though repeated harvesting increased total yield over uprooting, this cannot be universally generalized, it is dependent on, at least, variety type.

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Introduction

The Amaranth (*Amaranthus* spp), consisting of several cultivated of a more than 60 species genus, is strongly endorsed as a vital crop owing to its many advantages. The crop is easily accessible and affordable to low income earners living in urban, peri-urban and rural areas (Gotor and Irungu, 2010). It can be effectively cultivated in semi-arid areas (Myers, 1996) because it is able to adapt to adverse conditions including low soil nutrients fertility, ranges of temperature, radiation, and soil moisture stress (drought). As an income generator where it is cultivated, Amaranthus also has great potential to contribute to securing food, nutrition and health of innumerable consumers of the crop. It is an easy to establish crop and fast growing. It can generally be ready for harvest as a vegetable within 4 – 6 weeks (Barua *et al*., 2018; Awe and Osunola, 2013), whereupon vegetable yields as high as 53.4t/ha has been reported in Canada (Farintosh *et al*., 2020), even though most high yields are reported to be around 30t/ha (Barua *et al*., 2018; Birhanu *et al*., 2024).

Nutritional importance of the Amaranthus crop is unprecedented. It is a grain crop generally recognized as a "pseudo-cereal"; which means it is comparable with the staple cereal crops like maize, wheat and paddy, even though the cereal grain crop use of Amaranth is generally under-utilized or totally un-utilized especially in African contexts. Most of recognized importance of Amaranthus is when it is used as a leafy vegetable. It is a highly celebrated leafy green accompanying many staple meals; in many instances used as a sole enabler of consuming staple meals like "ugali" (stiff maize/sorghum/cassava porridge) which is the most extensively consumed meal among resource poor individuals in Tanzania and perhaps most of East Africa.

Amaranth is a highly nutrient dense vegetable and grain. It is rich in proteins, containing about 13 – 19% protein in grains and in leaves 23- 25% (Joshi and Rana, 1995). More ever, quality of the protein in Amaranthus is superior, with amino acids deficient in other plant proteins (Ibid). These amino acids are lysine and methionine. Amaranth is a rich source of iron and therefore often recommended as a nutritional source in medical correction of anaemic conditions. It is also rich in other minerals: Calcium, Potassium, Sodium, Phosphorus, Zinc, Copper, Magnesium and Manganese (Grubben and Denton, 2004; Awe and Osunola, 2013; Barua *et al*., 2018) and it is an excellent source of several vitamins: Vit. A, K, B6, C, B2 [Riboflavin], B3 [Niacin], B9 [Follate/folic acid] (Oyenuga and Fetuga, 1975; Awe and Osunola, 2013). When consumed as a vegetable Amaranth also has strong anti-oxidant properties thus considered worthy in prevention of ageing related diseases notably diabetes, arteriosclerosis, cancer, hypertension, high cholesterol levels; and in the management of HIV/AIDS (Barua *et al*., 2018; Awe and Osunola, 2013).

Two generally cultivated botanical groups of Amaranthus, grain and vegetable Amaranths, can be adapted to different harvesting protocols when cultivated as a vegetable. Even though especially the grain types are practically a dual vegetable and grain crop, typical of vegetable types may have features that suit them more in specific agronomic practices such as harvesting method while grain types also have features capitalizing on grain production more preferably. The grain types, which are actually the predominant group in Tanzanian production systems of the crop, are generally predominantly erect growing plants with inflorescences predominantly apical with none or very limited and less developed panicles from side branches. Typical of vegetable types owing to their more extensive branching ability produce multitudes of small panicles from many side branches in addition to the main stem and usually comparatively smaller panicle.

Whether vegetable or grain type, what appears most as harvesting method of Amaranthus as a vegetable crop is harvesting once by uprooting or cutting the stem at soil level; or by repeated harvesting of tender shoots or branches, notably termed: plucking, topping, cut-back or tipping (Norman and Shongwe, 1993; Awe and Osunola, 2013; Maboko and Du Plooy, 2012; Gichunge *et al.*, 2009; Matechera and Madupe, 2006; Mnzava and Ntimbwa, 1985; Ribeiro, 2004; Olujide and Oladele, 2007).

In Tanzania harvesting once by uprooting or cutting at soil level is what is practiced most. Some literature report topping to be the most practiced method (Olufolaji, 1989) but this is not inclusive of Tanzania. Where choice of harvesting technique can be an option, variety or cultivar of the crop used can be determinant. Another important determinant is system of the crop production; whether commercial gardens or home site or backyard gardens. Repeated harvesting is more suited in backyard gardens and the intense branching vegetable variety types become more preferable in the home gardening context. In commercial gardens harvesting once is more preferable because of the larger scale of production to satisfy outlet markets, ease of handling the uprooted plants which can be easily tied in bunches that can be more precisely estimated in relation to selling price. When harvesting by picking, selling becomes in piles. The piles are more difficult to handle in transportation if commercially significant quantities; and in the market, table piles would occupy more space and are more difficult to estimate quantity and price. All these inconveniencies, in addition perhaps to slower biomass growth or less biomass at critical vegetable harvesting timing which is at the beginning of inflorescence appearance in the crop population, make harvesting once and in bunches more preferable production cycles.

Nevertheless, several authors report better vegetable harvests when harvesting is repeated method rather than uprooting or harvesting once (Awe and Osunola, 2013; Bello *et al.*, 2011; Grubben, 2004).

Even though some extent of cultivation of Amaranthus using repeated rather than uprooting method of harvesting is practiced in Tanzania, there is generally very limited information available, detailing on how the harvesting of the vegetable can be optimized. Some information of research conducted half a century previously has been accessed during current literature search (Mnzava and Ntimbwa, 1985; Mnzava and Masam, 1985), abstracting on research on repeated harvesting. Details have been, however, still missing on comparative vegetable yield against uprooting and influence of Amaranth type (grain or vegetable) and possibly varieties in use. This has been the gap that compelled currently reported experimentation.

Materials and methods

The experiment was conducted at the Crop museum experimental field of Sokoine University of Agriculture during the 2nd quarter of 2024. Harvesting by clipping or by uprooting was exercised.

Clipping was performed such that twigs were cut either half or quarter of the twig height from the lowest leaf node of the twig. Timing of twig removal ensured that the harvesting was performed before twigs formed inflorescences, as soon as there was 1st indication of inflorescence in one of the plants in the plot. This roughly turned out to be 14 – 21 days after the preceding harvest. The harvesting started about 35 days after planting. Three different varieties of Amaranthus were used in this experiment; one of them grain type and two of them typically vegetable ones with black grains and less dominance of a single, centrally apical inflorescence.

One of the vegetable types was a commercial seed source variety while the other was a traditional local seed source variety.

Seeds of the varieties were sown by dibbling at a spacing of 40cm x 20cm in each plot according to treatment. Each treatment was replicated three times. Abundant quantity of cattle manure (≈ 50t/ha) was incorporated in each plot during land preparation and leveling of the plots. After seedlings emergence each hill was thinned to remain with one plant per hill, 2 weeks after sowing. Irrigation was performed everyday especially at seedling stage. Weeding was performed as necessary to keep the experiment weed free. Harvesting was performed beginning from 35

DAP and where it was repeated it continued consecutively for approximately 8 weeks.

Measurement of the harvested crop was performed immediately after each plot was harvested, then fresh weight data compiled. The data were then subjected to analysis of variance and mean separation to establish statistical relevance of data variation.

Results and discussion

Data from the experiment are elaborated as presented in tables, whereupon Table 1 shows overall statistical response of the Amaranthus yield as influenced by the experimental treatments.

Genotypes as treatments as well as harvesting techniques and the interactions all showed some significant influences. Genotypes influence was significant for the 1st up to 5th harvest yields as well as the overall (total) yield, while effect of harvesting was significant for the 1st, 2nd and 3rd yields ($P < 0.05$). Interaction of genotypes and harvesting techniques was significant for the 1st harvest and total yields.

Table 1. Summary of analysis of variance results (mean sum of squares) for the effects of various vegetable harvesting techniques on various Amaranthus crop genotypes

Source of variation	df	Mean sum of square values					
		1st harvest yield	2nd harvest yield	3rd harvest yield	4th harvest yield	5th harvest yield	Total yield
Replications	2	18790	302268	3549	10176	1595	352910
Genotypes	2	2912401***	1836604***	297421***	443653***	79423***	1306720**
Harvesting	2	742523***	437156**	21742*	2252	2737	709296
Interaction	4	651891***	120394	11368	601	1870	1365013**
Error	16	39249	67467	4449	15198	1804	200790

* Significant at 0.05 level ** Significant at 0.01 level *** Significant at 0.001 level

Table 2. Fresh vegetable yield of Amaranthus as a result of harvesting technique and genotypes

Genotype	Yield according to genotypes		Yield according to harvesting technique	
	Amaranth type	Yield (t/ha)	Technique	Yield (t/ha)
GTP 24	Vegetable	18.2	Uprooting	11.51
GTP 25_01_1	Grain	16.68	Clipping ½ length	18.47
Variety 1	Vegetable	12.76	Clipping ¼ length	17.67
Mean		15.88		15.88
CV %		28.2		45.1
Probability		0.009		0.054

Table 3. First harvest and repeated harvest fresh yield variation of different Amaranthus vegetable harvesting techniques

Technique	Yield 1st harvest	2nd harvest	3rd harvest	4th harvest	5th harvest
	(Kg/m^2)	(Kg/m^2)	(Kg/m^2)	(Kg/m^2)	(Kg/m^2)
Uprooting	1.1506	-	-	-	-
Clipping ¼	0.1683	0.8189	0.3122	0.3845	0.1627
Clipping ½	0.1622	0.7400	0.3174	0.3839	0.1633
Mean	0.494	0.7794	0.3148	0.3845	0.1630
$LSD_{0.05}$ [a]	0.4529	0.3253	0.0834	0.1042	0.0426
Probability	0.001	ns	ns	ns	ns

ns = not significant Excludes "zero" data for uprooting, which did not exist from 2nd – 5th harvests

[a] Based on ANOVA results where "no yield (zero)" data from uprooting 2nd – 5th harvests was included

Table 2 shows mean variation of individual influences of genotype and harvesting techniques on yield of the Amaranthus crop. The influence of harvesting techniques on vegetable yield, independent of genotypes, was not significant ($P = 0.054$) even though the coefficient of variability was also high (45.1%). Influence of genotypes independent of harvesting techniques, in the contrary, was very significant, (P < 0.01). From this experiment it seems clipping whether quarter length or half length of the shooting branch would result into almost the same yield.

Table 3 presents' details of data of the 1st (once) and repeated harvest yields according to different harvesting techniques experimented. As it would have been expected, variation in yield during the 1st harvest was extensive and very significant owing to uprooting treatment, since fresh weights of whole plants were measured after the harvest, against only small portions of the plant (upper ½ or ¼ of length of plant from the lowest leaf node). The 2nd – 5th harvests involved only the clipping methods and variation between the two treatments did not seem to be significant.

Table 4 shows combined response of the crop to interactive influence of genotypes and harvesting techniques, and yield advantage or disadvantage when uprooting was used as baseline. The results suggest strong determinant power of variety of the crop on harvest yield when different harvesting techniques are practiced; and segregates clearly the distinction between vegetable and grain types. While in the vegetable types uprooting exhibited very significantly much lower yields against clipping, in the grain type (GTP 25_01_1) uprooting led to highest yield and with clipping showing yield disadvantage ranging from roughly 26 – 34%. Yield advantage of clipping in the vegetable types was as high as 213.7%, meaning that in one instance (GTP 24, clipping ¼ length) the yield was slightly more than 3 times that of uprooting.

Table 4. Combined response of Amaranthus vegetable yield to genotypes and uprooting or clipping harvesting techniques

Genotype	Harvesting	Total yield (t/ha)	Yield advantage (for genotype)*	% difference over uprooting	Mean % difference
GTP 24	Uprooting	7.72 de	-	-	
	Clipping ¼	24.22 a	+ 16.5	+ 213.7	+ 203.6
	Clipping ½	22.66 ab	+ 14.94	+ 193.5	
GTP 25_01_1	Uprooting	20.95 abc	-	-	
	Clipping ¼	13.77 cde	- 7.18	- 34.3	- 30.1
	Clipping ½	15.33 bcd	- 5.62	- 25.8	
Variety 1	Uprooting	5.85 e	-	-	
	Clipping ¼	17.42 abc	+ 11.57	+ 197.8	+ 177.2
	Clipping ½	15.01 bcd	+ 9.16	+ 156.6	
Mean		15.88			
CV (%)		28.2			
Probability		0.002			

*Tons/ha. Uprooting is used as base. Means bearing the same letter in the total yield column are not significantly different according to Tukey mean separation (P<0.05).

This study unlocks a hidden secret of traditional varieties. As the statistics show, yield increased by more than 200% in GTP 24, which is a traditional variety locally known as Bwasi in Morogoro, when clipping was practiced against uprooting. In Variety 1, which was commercial seed but also a traditional, black seed vegetable type not very different from the other local variety (GTP 24) phenotypically, yield increased by on average 177% when clipping was practiced over uprooting. In the contrary, in the non-traditional, grain type genotype GTP 25_01_1, which generally constitutes derivatives of materials introduced perhaps in the 1970s or 1980s and typical of South American cultivated types, yield was decreased by on average 30% when clipping was contrasted with uprooting. When clipping was used as base, uprooting increased yield by up to > 50% in this grain type genotype. We can therefore say that opposite parallels exist between vegetable and grain types with regard to single and multiple harvest techniques.

Results of this research confirm the assertion that repeated harvesting can be considered leading to greater production than a single harvest, as pointed out in work of Grubben, 2004; Bello *et al.*, 2011 and Awe and Osunola, 2013. It has been found in this research repeated harvesting averaging yield (beyond genotype × harvesting interactions) as high as 18.47t/ha against 11.51t/ha from uprooting; an increase of more than 60%. This owes to much more stimulated growth, from multiple axillary rather than only or predominantly one, apical terminal growing point, when the growing shoot is topped (cut back). Further investigation has, however, also revealed that the prospect of higher yields when harvesting is repeated rather than uprooting (once) cannot be universally generalized. It can be different for different varieties, as it has been reported for the grain type variety in this research. It is also important to note that individual influence of varieties or genotypes on yield of the vegetable was very significant but was amplified further when harvesting technique was also a consideration.

Conclusion

This study established that repeated harvesting results into greater yield of the vegetable, even though this cannot be generalized in all varieties or variety types. While it was evidently better (repeated harvesting) in Vegetable variety types, in a grain type variety, yield from single harvest uprooting was greater than in repeated harvesting by a margin reaching > 50%. Therefore where repeated harvesting is an option, consideration of type of variety in question is necessary, at least whether it is grain or vegetable type.

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