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Participatory Selection of Amaranthus Genotypes in the KwaMbonambi Area, KwaZulu-Natal, South Africa

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Abstract: Participatory variety selection (PVS) is a process that tests promising genotypes in farmers' fields through a close farmer–researcher collaboration approach, which enhances the acceptance of new varieties by farmers. However, limited studies have been conducted to select *Amaranthus* genotypes that have potential for future breeding programmes in South Africa. Therefore, this study was aimed at selecting *Amaranthus* genotype(s) that is/are preferred by farmers in northern KwaZulu-Natal, using the PVS approach. Seedlings of fifteen *Amaranthus* genotypes were each planted in separate 10 × 10 m plots. Fourteen local farmers managed these genotypes and also determined the preferred traits to be used to evaluate them. These traits were: mild taste; profuse stem branching; big and numerous leaves; soft texture; and longer shelf life. Plants at four months after transplant were then evaluated and ranked according to farmers' preferred traits using score sheets designed on a four-point Likert scale or five-point hedonic scale. However, genotype ACAT seed fair had the best scoring for appealing taste and aroma, and profuse branching. The TOT 8789 genotype had the largest and softest leaves. Again, *A. thunbergii* had the most numerous leaves of them all. These genotypes are thus recommended for multi-environment testing, seed multiplication, genetic improvement, and promotion for cultivation in South Africa.

Keywords: Amaranth; genotype; participatory variety selection; pig weed; traditional leafy vegetable

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1. Introduction

Participatory variety selection (PVS) is a selection process that involves a close farmer–researcher collaboration in testing released or promising genotypes in the farmer's field [1]. This approach helps determine varieties that farmers want to grow; identify traits that farmers value; determine the gender differences in varietal selection criteria; and enhance speedy acceptance and cultivation of new varieties by farmers [2]. It also overcomes the disadvantage imposed by modern plant breeding where improved varieties are selected in favourable environments that do not represent the actual conditions to which a particular plant will later be subjected [3].

In PVS, farmers are provided with a basket of genotypes for matching with their own selection criteria [4]. This offers farmers the possibility to choose, in their own environment, the varieties that are better suited to their needs and conditions [5]. It also helps to identify and assess traits that are important to small-scale farmers, especially subjective traits such as taste, aroma, appearance, texture, storage quality and other culinary qualities, which are difficult to measure quantitatively [6]. Survey studies, transect walks and focus group discussions also form part of the PVS programme to assist with identifying farmers' needs through the participatory rural appraisal (PRA) approach [7,8].

The genus *Amaranthus* belongs to Amaranthaceae family, with many species that originated from South America [9]. It contains more than 60 species that are often cultivated as leafy vegetables, ornamental plants, and grains [10,11]. The consumable parts include young leaves, shoot tips and whole seedlings that are harvested in fallow lands and fields mainly during summer [9]. In most rural areas, the harvested *Amaranthus* is cooked and consumed as a relish with staple foods [12]. Some *Amaranthus* species are used to treat various ailments such as skin, gastro-intestinal, pulmonary, and urinary diseases [11,13,14].

Amaranthus genotypes are reported to be tolerant of adverse environmental conditions [11], such as heat, drought, diseases [13] and they have high nutritional value [14,15]. In spite of the high nutrient content, vegetable *Amaranthus* has received significantly less research attention than grain *Amaranthus* [14]. Additionally, in South Africa, *Amaranthus* is rarely cultivated because it is believed that it will grow spontaneously [16,17].

In a study of farmers' preferences, traits such as taste, aroma, leaf yield, texture, taste, colour, and shape are important in choosing among *Amaranthus* genotypes [18]. However, there are no sensory analysis studies that have been conducted on the different *Amaranthus* genotypes in South Africa [9]. Therefore, the aim of this study is to select *Amaranthus* genotypes that are preferred by farmers, using the participatory variety selection approach. The information generated through PVS will further assist with identification of farmer-preferred traits that could be incorporated in future *Amaranthus* breeding programmes.

2. Materials and Methods

2.1. Study Design

This study was conducted with a selected group of rural farmers who were members of an agricultural co-operative. As such, no sampling of respondents was necessary, and all members participated. The study design was therefore a case study.

2.2. Plant Material

Fifteen *Amaranthus* genotypes were supplied by the Agricultural Research Council—Vegetable and Ornamental Plant Institute (ARC-VOPI) genebank (Table 1). These particular *Amaranthus* genotypes were selected because they were uncharacterised accessions for consumer acceptability [19,20]. However, some of the accessions listed in Table 1 were preliminarily characterised for morphological [9,17] and nutritional traits [15]. As a result, there were still many information gaps regarding their characterization; preferred traits; as well as their yield-related traits, which need research attention. The names of the *Amaranthus* genotypes, their origin, and brief morphological differences are given in Table 1.

Table 1. *Amaranthus* genotypes evaluated in participatory genotype selection.

Scientific Name	Genotype	Origin	Morphology
Amaranthus cruentus L.	AMES-22680	USA	Green leaves with purple patches
Amaranthus cruentus L.	AM-fune	Tanzania	Zig-zag stems with green leaves
Amaranthus cruentus L.	Anna	Germany	Green leaves with wavy margins
Amaranthus cruentus L.	Arusha	Tanzania	Green and long leaves with entire margins
Amaranthus cruentus L.	Kobie	Unknown	Straight stems with green, soft leaves
Amaranthus dubius Mart. ex Thellung	TOT 8789	Unknown	Green, large and soft leaves
Amaranthus greacizans L.	Thohoyandou	SA, Limpopo	Reddish stems, petioles and veins. Lamina also has reddish tints
Amaranthus hybridus L.	TOT 2266	Unknown	Green soft leaves with prominent veins
Amaranthus hybridus L.	TOT 2358	Unknown	Green leathery leaves with prominent veins
Amaranthus thunbergii Moq.	A. *thunbergii*	SA, Kwa-Zulu Natal	Green, small leaves with wavy margins
Amaranthus tricolor L.	Tricolor PI462179	USA	Reddish stems with lanceolate, reddish leaves with dentate and wavy margins
Amaranthus viridis L.	W6297N	USA	Purplish stems with green leaves
Amaranthus sp.	ACAT seed fair	SA, Kwa-Zulu Natal	Purplish stems and lower leaf surfaces
Amaranthus sp.	Tanzania	Tanzania	Green, medium-sized, soft leaves
Amaranthus sp.	TOT 4151	Unknown	Purple foliage

SA—South Africa; USA—United States of America. Adapted from Gerrano et al. [9].

2.3. Plant Management

Seeds were sown in trays in a greenhouse at the Agricultural Research Council, Vegetable and Ornamental Plant Institute (ARC-VOPI), Roodeplaat research farm, Pretoria (25°59′ S and 28°35′ E). Several seeds were sown per cell. Emergence commenced five days after sowing. Thinning was done three weeks after planting to leave one plant per cell. In the fourth week after planting, the *Amaranthus* seedlings were transported to the Isabelo Co-operative field at KwaMbonambi, KwaZulu-Natal, South Africa (28°36′0″ S, 32°5′0″ E). A total of 14 farmers of this co-operative received seedlings of each genotype which they transplanted into their own fields in 10 m × 10 m plots with an inter-row spacing of 1.5 m and an intra-row spacing of 0.3 m. This equated to a total 210 plots (14 farmers × 15 genotypes) used for evaluation. Each genotype had one plot as the experiment was not replicated because it was a demonstration plot and did not require the collection of replicated data (n = 14). Weeding and irrigation was carried out manually when necessary. No fertiliser was applied since rural farmers typically do not apply fertiliser when cultivating traditional leafy vegetables. Transplanting was done on 14 November 2017 and termination was on 22 March 2018.

2.4. Data Collection

2.4.1. Evaluation of Genotypes Based on Selection Criteria

The same fourteen farmers (ten females and four males) of Isabelo Co-operative who grew the genotypes participated in the evaluation study. The participants were allowed to set their own selection criteria, which were: stem branching; leaf size; number of leaves per plant; leaf texture; taste; aroma; as well as shelf life (yellowing and wilting status after harvest). The participatory variety selection activities were conducted on one occasion, at four months after transplanting seedlings to the field (22 March 2018). However, the shelf life was determined by keeping the harvested shoot tips in open containers under room temperature (25 °C) and evaluating them at seven days after harvest (29 March 2018). An empty plastic container was then placed in front of each plot. Each participant and a researcher then walked through the plots and discussed the traits of different lines. During that discussion, each participant was given a cup filled with bean seeds to select the best genotype for specific traits by dropping between one to four seeds in the container placed in front of the plots. Using a scale from one to four, each participant dropped beans in the containers placed by each plot and this process was repeated for each trait. In ranking exercises, the highest score (4) was given for the most preferred traits and the lowest value (1) for the least preferred ones.

Both field and organoleptic evaluations were conducted on the same day (22 March 2018). Shoot tips of each genotype were harvested, washed repeatedly with water until clean, and chopped into small pieces. Chopped pieces of each genotype were transferred into pots without any additional water and allowed to boil with the moisture accumulated from the washing. While cooking for a duration of about 10 min or until the shoots were soft for consumption, a pinch of salt was added. A wooden spoon was used to mix the salt until it was completely dissolved. The cooked *Amaranthus* shoots were kept in separate labelled containers at room temperature and served to evaluate the taste and aroma. Leaf texture was evaluated before and after cooking. In between each sampling, panellists rinsed their mouths at least twice with water during a one-minute break. A five-minute break was given between different plots to prevent fatiguing and also to record each respondent.

Data were collected using a score sheet which was adapted from [19,21] (Appendix A Tables A1–A6). Questions in the score sheet were asked in vernacular language and responses were filled in by the researcher after listening to the replies and understanding the responses of each participant. The total score was calculated for each criterion. Responses were adapted to a four-point Likert Rating Scale (LRS), as poor (P) = 1; fair (F) = 2; good (G) = 3; and excellent (E) = 4. The mean score was computed as 4 + 3 + 2 + 1 = 10/4= 2.50. Using the interval score of 0.05 the upper limit cut-off was determined as 2.50 ± 0.05 and the lower limit as 2.55 ± 0.05 = 2.45. On this basis, a mean score (MS) below 2.45

(i.e., < 2.45) was ranked 'low'; those between 2.45 and 2.54 were considered 'medium' (i.e., 2.45 $\geq$ MS $\leq$ 2.54); while the mean scores greater than or equal to 2.55 (i.e., MS $\geq$ 2.55) were considered 'high' [19,21].

2.4.2. Shelf Life Determination

For each genotype, forty-five leaves from each plot were harvested randomly in the morning and bundled. The bundles were then placed in separate plastic crates and kept at room temperature storage at the co-operative house. The *Amaranthus* leaves were then evaluated after seven days by the respondents on the basis of leaf colour and wilting using the simple 5-rating scales; the limit of acceptance was 2.5 (a score lower than 2.5 indicated poor quality). Colour was determined using a 5-point hedonic scale, where 1 = dark-green, 2 = light-green, 3 = yellowish-green, 4 = greenish-yellow, 5 = yellow. The extent of wilting was assessed on the basis of a 5-point hedonic scale, where 1 = extreme, 2 = severe wilting, 3 = moderate wilting, 4 = slight wilting, 5 = none.

2.4.3. Data Analysis

Descriptive statistics such as frequencies, counts, and percentages were used to analyse socio-demographic variables, while a Likert Scale was used to analyse the farmer's preferences. Data analysis was done using IBS SPSS (2016) version 24 software [22].

3. Results and Discussion

3.1. Gender and Age of the Respondents

The number of female respondents across all age categories was higher than the males (Figure 1). This is possibly because the Isabelo co-operative, which participated in the research, has more female than male members. The ages of respondents ranged from 18 to above 55 years old (Figure 1), with the majority being middle-aged females between 35 and 55 years old followed by the old-age females of above 55 years old.

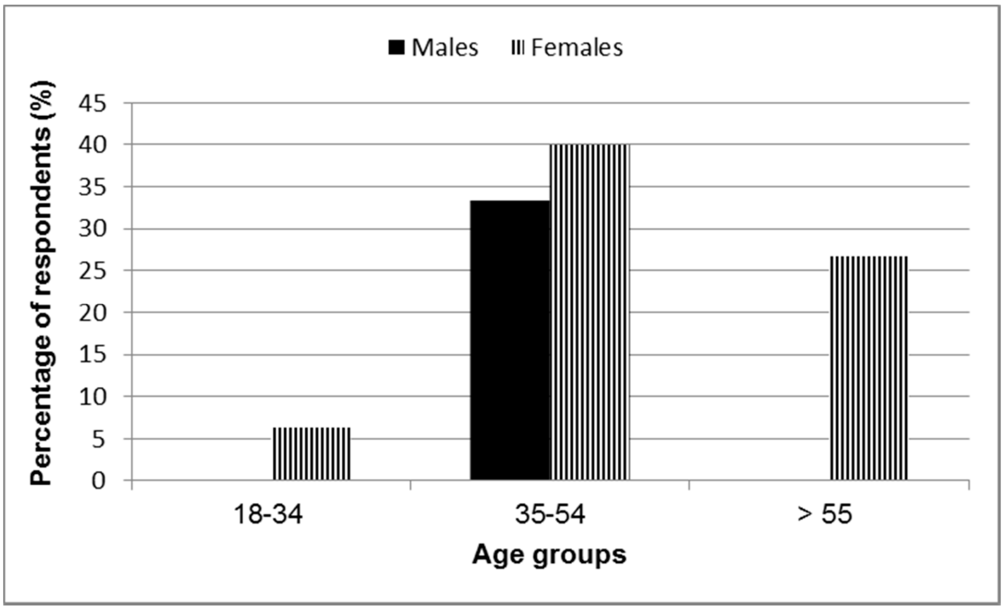

Figure 1. Gender and age of the respondents.

The young age group (18–34 years) had the least number of respondents. One reason could be that some members of this age group in the community are still attending school. Furthermore, various studies have shown involvement of youth in agriculture in South Africa to be low and this could also explain the low number of respondents in this age group [16,23–25]. Young people normally perceive traditional leafy vegetables as a 'poverty crop', and therefore do not want to associate themselves with the indigenous knowledge regarding the production and consumption of such vegetables [23]. Youth also regard the preparation and cooking methods of traditional leafy vegetables as tedious and opt for the consumption of modern crops such as spinach [23]. Again, the decline of youth involvement in agricultural practices in rural areas is associated with their migration to urban areas to seek other jobs due to the low status associated with farming [24]. However, Ntuli [25] found that most respondents were young-aged males in a survey done in the Umkhanyakude district of Northern KwaZulu-Natal.

3.2. Availability and Cultivation of Amaranthus Genotypes

Amaranthus thunbergii and *A. viridis* (W6297N genotype) were known by all respondents as occurring in the area, while the rest of the genotypes were unknown to the respondents prior to this study. *A. viridis* was known to occur abundantly in the area, while *A. thunbergii* was rare because it was believed to be severely affected by drought. In this community, *Amaranthus* was rarely cultivated but harvested on fallow land and from maize fields, where they are left undisturbed during weeding for future use. This is related to former reports that in South Africa, *Amaranthus* is seldom cultivated because as with many other traditional leafy vegetables people believe that the plants will grow naturally [20,26].

3.3. Stem Branching, Leaf Size and Leaf Number

In the current study, genotypes ACAT seed fair, AMES-22680 and TOT 8789 were the most preferred for profuse stem branching (Table 2). Stem branching is a desirable horticultural trait that serves as an important index of leaf yield [9,27].

The highest mean score for bigger leaf size was given to genotypes TOT 8789, ACAT seed fair, AMES-22680, Arusha and W6927N, whereas the lowest mean score was associated with *A. thunbergii* and genotype Tanzania in the current study (Table 2). In Kenya, there is a definite preference for *A. hybridus* compared to *A. cruentus* due to its broad leaves [28]. Again, the smaller leaves *of A. greazicans* are identified as a clear drawback during its harvesting [12]. This suggests that bigger leaf size would be a good selection criterion for improved yield in Amaranthus genotypes.

The current study also showed that *A. thunbergii* ranked last for leaf size but first for number of leaves (Table 2). Respondents reported *A. thunbergii* as producing smaller and more numerous leaves when subjected to water stress, but larger and fewer leaves when exposed to adequate water supply. A study by Adenjii et al. [29] reported high preference for *Amaranthus* genotypes with a bigger leaf size. The above study further concluded that from a plant breeder's point of view, such genotypes could serve as donor parents where a large leaf size is sought.

Table 2. Ranking of preferred traits for evaluated *Amaranthus* genotypes.

Genotype	Stem Branching		Leaf Size		Leaf Number		Soft Leaf Texture		Taste		Aroma		Colour after Harvest		Wilting	
	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank
AMES-22680	2.70	2	3.49	3	3.20	4	3.06	4	2.99	4	2.99	4	3.00	1	2.00	1
AM-fune	2.21		1.70		1.70		2.06		1.00		0.21		3.00	1	2.00	1
Anna	1.00		2.56	6	3.70	3	2.42		1.00		0.21		3.00	1	2.00	1
Arusha	2.42		2.92	5	3.20	4	3.28	3	2.35		2.35		3.00	1	2.00	1
Kobie	1.00		1.63		1.50		1.99		1.20		1.20		3.00	1	2.00	1
TOT 8789	2.56	3	3.64	1	1.50		4.00	1	1.00		0.21		3.00	1	1.00	3
Thohoyandou	1.00		1.85		1.78		1.00		1.99		2.88	5	3.00	1	2.00	1
TOT 2266	1.00		1.35		1.28		2.27		1.99		2.14		3.00	1	2.00	1
TOT 2358	1.00		1.85		1.78		2.21		1.00		0.21		3.00	1	2.00	1
A. thunbergii	1.00		1.00		3.84	1	3.05	5	3.50	3	3.50	2	3.00	1	2.00	1
Tricolor PI462179	1.00		1.50		0.64		3.84	2	1.00		0.21		3.00	1	1.00	3
W6927N	1.71		3.00	4	3.34	2	2.50		2.50	6	3.00	3	3.00	1	2.00	1
ACAT seed fair	3.42	1	3.56	2	3.34	2	1.13		3.92	1	3.92	1	3.00	1	1.93	2
Tanzania	1.00		1.78		1.56		1.13		3.70	2	3.50	2	3.00	1	2.00	1
TOT 4151	1.70		2.42		1.92		1.06		2.50	6	3.00		3.00	1	2.00	1

3.4. Leaf Texture, Taste and Aroma

Texture is a very important factor in consumer preference [30]. Based on both tactile and oral evaluation of the various genotypes, respondents indicated that genotype TOT 8789, followed by Tricolor P462179 were highly preferred for soft texture before and after cooking (Table 2). However, the softness of genotype TOT 8789 resulted in a mucilaginous texture after cooking which was considered undesirable to respondents. Ames-22860 scored low for texture in a previous study [9] yet was ranked fourth for soft leaf texture in the current study. Genotypes TOT 2266 and Thohoyandou also scored high for texture in their study, but they had a relatively low score in the current study.

In the combined evaluation of aroma and taste in cooked *Amaranthus* genotypes, genotype ACAT seed fair ranked first (3.92) followed by Tanzania (3.5) and then *A. thunbergii*, AMES-22680, Arusha, TOT 4151 and W6927N with mean score values above 2.5 (Table 2). This implied the possibility that any of these genotypes could be selected when breeding for taste. In a study conducted in the Free State province, South Africa, genotype TOT 2266 obtained the second highest rank for taste [9], whereas in the current study it was ranked as the eighth in genotype preference for the same trait (Table 2). Similarly, AMES- 22680 which was ranked fourth for mild-taste in the current study, was found less acceptable due to bitter taste in the previous study [9]. Differences in taste perception of the same genotypes in these studies might be due to differences in agro-environmental conditions during production and post-harvesting [31]. In addition to favourable taste, genotypes ACAT seed fair and Tanzania were also preferred for good aroma (Table 2). Genotypes AM-fune (*A. cruentus*) and Thohoyandou (*A. greazicans*) were least preferred due to their bitter taste, while Tricolor PI462129 (*A. tricolor*) was described as tasteless. These findings are similar to those recorded in the Free State, where respondents also described genotype Thohoyandou and *Tricolor* PI462129 as bitter and tasteless, respectively [9].

The preference for taste was not affected by gender, with both males and females preferring mild tasting genotypes. These findings are in agreement with the former reports in northern KwaZulu-Natal that no gender differences are noted with *Amaranthus* in terms of preferences for taste [27]. By contrast, a study which included several villages across South Africa recorded that men prefer the bitter tasting leafy vegetables, whereas women and children prefer mild-tasting ones [32]. This unanimous genotype preference in both genders shows the possibility to improve *Amaranthus* genotypes in KwaMbonambi to meet the preferences of both males and females.

3.5. Shelf Life

Several studies on traditional leafy vegetables identified short post-harvest shelf life as the main constraint to their consumption [26,31,32]. Both yellowing and wilting are indicators that fresh leafy produce has reached the end of its shelf life [33,34] and these characteristics were thus used to assess shelf life in this study.

In the current study, leaves of all *Amaranthus* genotypes changed from green to yellowish green seven days after harvesting (Table 2). Assessment further showed all the *Amaranthus* genotypes were given an average mean score of 2.00 or less for wilting, which implies that respondents viewed all tested genotypes as highly perishable (Table 2). It was also observed that the soft textured *Amaranthus*, namely TOT 8789 and Tricolor p462179 were more susceptible to wilting compared to other genotypes (Table 1). African indigenous leafy vegetables with high moisture content exhibit high metabolism after harvest and are highly perishable, with a shelf life of less than a day under tropical temperatures [32]. These results show a need for improved post-harvesting handling methods and possible genetic improvements for prolonged shelf life in the tested *Amaranthus* genotypes.

4. Conclusions

The participatory approach emphasised that farmers in the KwaMbonambi area preferred *Amaranthus* genotypes with an appealing taste and aroma; many branches; large, numerous and soft leaves; and longer shelf life. ACAT seed fair genotype scored the highest in terms of palatability, appealing aroma, and branching. Again, TOT 8789 genotype was the best in terms of large leaf size and soft texture. Further, *A. thunbergii* had the most numerous leaves of all genotypes. Therefore, these genotypes have potential for future breeding programmes that focus on trait improvement and hybridisation. This breeding would focus on producing cultivars that, as much as possible, have most of the preferred traits as indicated by the participants and these cultivars would be made available to farmers. The small sample size in this study was a limitation and future studies will be improved by using a larger number of participants.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of the University of Zululand (protocol code UZREC171110-030 PGM2017/372 as approved on the 4 November 2017).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Respondents' evaluation and ranking of *Amaranthus* genotypes according to stem branching (n = 14).

Scientific Name	Genotype	Excellent (4) *	Good (3) *	Fair (2) *	Poor (1) *	Mean Score	Rank
A. cruentus	AMES-22680	1 (0.28)	8 (1.71)	5 (0.71)	0 (0)	2.70	2
A. cruentus	AM-fune	0 (0)	3 (0.64)	11 (1.57)	0 (0)	2.21	
A. cruentus	Anna	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. cruentus	Arusha	0 (0)	0 (0)	10 (1.42)	14 (1.00)	2.42	4
A. cruentus	Kobie	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. dubius	TOT 8789	0 (0)	8 (1.71)	6 (0.85)	0 (0)	2.56	3
A. greacizans	Thohoyandou	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. hybridus	TOT 2266	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. hybridus	TOT 2358	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. thunbergii	*A. thunbergii*	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. tricolor	Tricolor PI462179	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. viridis	W6927N	9 (0.64)	5 (1.07)	0 (0)	0 (0)	1.71	
Amaranthus sp.	ACAT seed fair	6 (1.71)	8 (1.71)	0 (0)	0 (0)	3.42	1
Amaranthus sp.	Tanzania	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
Amaranthus sp.	TOT 4151	0 (0)	0 (0)	10 (1.42)	4 (0.28)	1.70	

* Number outside bracket represents number of respondents. Number inside the bracket = sample number of respondents (n)/[the total number of respondents (N) × Likert scale rating].

Table A2. Respondents' evaluation and ranking of *Amaranthus* genotypes according to leaf size and number (n = 14).

Scientific Name	Genotype	Leaf Size					
		Excellent (4) *	Good (3) *	Fair (2) *	Poor (1) *	Mean Score	Rank
A. cruentus	AMES-22680	7 (2)	5 (1.07)	2 (0.42)	0 (0)	3.49	3
A. cruentus	AM-fune	0 (0)	0 (0)	10 (1.42)	4 (0.28)	1.70	
A. cruentus	Anna	0 (0)	8 (1.71)	6 (0.85)	0 (0)	2.56	6
A. cruentus	Arusha	4 (1.14)	5 (1.07)	5 (0.71)	0 (0)	2.92	5
A. cruentus	Kobie	0 (0)	0 (0)	9 (1.28)	5 (0.35)	1.63	
A. dubius	TOT 8789	9 (2.57)	5 (1.07)	0 (0)	0 (0)	3.64	1
A. greacizans	Thohoyandou	0 (0)	0 (0)	12 (1.71)	2 (0.14)	1.85	
A. hybridus	TOT 2266	0 (0)	0 (0)	5 (0.71)	9 (0.64)	1.35	
A. hybridus	TOT 2358	0 (0)	0 (0)	12 (1.71)	2 (0.14)	1.85	
A. thunbergii	*A. thunbergii*	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. tricolor	Tricolor PI462179	0 (0)	0 (0)	7 (1.00)	7 (0.50)	1.50	
A. viridis	W6927N	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	4
Amaranthus sp.	ACAT seed fair	12 (3.42)	2 (0.14)	0 (0)	0 (0)	3.56	2
Amaranthus sp.	Tanzania	0 (0)	0 (0)	11 (1.57)	3 (0.21)	1.78	
Amaranthus sp.	TOT 4151	2 (0.57)	5 (1.07)	4 (0.57)	3 (0.21)	2.42	
		Leaf number					
A. cruentus	AMES-22680	3 (0.85)	11 (2.35)	0 (0)	0 (0)	3.20	4
A. cruentus	AM-fune	0 (0)	0 (0)	10 (1.42)	4 (0.28)	1.70	
A. cruentus	Anna	10 (2.85)	4 (0.85)	0 (0)	0 (0)	3.70	3
A. cruentus	Arusha	3 (0.85)	11 (2.35)	0 (0)	0 (0)	3.20	4
A. cruentus	Kobie	0 (0)	0 (0)	7 (1)	7 (0.50)	1.50	
A. dubius	TOT 8789	0 (0)	7 (1.5)	0 (0)	0 (0)	1.50	
A. greacizans	Thohoyandou	0 (0)	0 (0)	11 (1.57)	3 (0.21)	1.78	
A. hybridus	TOT 2266	0 (0)	0 (0)	4 (0.57)	10 (0.71)	1.28	
A. hybridus	TOT 2358	0 (0)	0 (0)	11 (1.57)	3 (0.21)	1.78	
A. thunbergii	*A. thunbergii*	12 (3.42)	2 (0.42)	0 (0)	0 (0)	3.84	1
A. tricolor	Tricolor PI462179	0 (0)	3 (0.64)	0 (0)	0 (0)	0.64	
A. viridis	W6927N	5 (1.42)	9 (1.92)	0 (0)	0 (0)	3.34	2
Amaranthus sp.	ACAT seed fair	5 (1.42)	9 (1.92)	0 (0)	0 (0)	3.34	2
Amaranthus sp.	Tanzania	0 (0)	0 (0)	8 (1.14)	6 (0.42)	1.56	
Amaranthus sp.	TOT 4151	0 (0)	9 (1.92)	0 (0)	0 (0)	1.92	

* Number outside bracket represents number of respondents. Number inside the bracket = sample number of respondents (n)/[the total number of respondents (N) × Likert scale rating].

Table A3. Evaluation and ranking of *Amaranthus* genotypes according to soft leaf texture before and after cooking by the respondents (n = 14).

Scientific Name	Genotypes	Excellent (4) *	Good (3) *	Fair (2) *	Poor (1) *	Mean Score	Rank
A. cruentus	AMES-22680	1 (0.28)	13 (2.78)	0 (0)	0 (0)	3.06	4
A. cruentus	AM-fune	0 (0)	4 (0.85)	7 (1)	3 (0.21)	2.06	
A. cruentus	Anna	0 (0)	6 (1.28)	8 (1.14)	0 (0)	2.42	
A. cruentus	Arusha	4 (1.14)	10 (2.14)	0 (0)	0 (0)	3.28	3
A. cruentus	Kobie	0 (0)	1 (0.21)	12 (1.71)	1 (0.07)	1.99	
A. dubius	TOT 8789	14 (4)	0 (0)	0 (0)	0 (0)	4.00	1
A. greacizans	Thohoyandou	0 (0)	0 (0)	0 (0)	14 (1)	1.00	
A. hybridus	TOT 2266	0 (0)	4 (0.85)	10 (1.42)	0 (0)	2.27	
A. hybridus	TOT 2358	0 (0)	3 (0.64)	11 (1.57)	0 (0)	2.21	
A. thunbergii	*A. thunbergii*	3 (0.85)	9 (1.92)	2 (0.28)	0 (0)	3.05	5
A. tricolor	Tricolor PI462179	12 (3.42)	2 (0.42)	0 (0)	0 (0)	3.84	2
A. viridis	W6927N	0	7 (1.5)	7 (1)	0	2.50	

Table A3. *Cont.*

Scientific Name	Genotypes	Excellent (4) *	Good (3) *	Fair (2) *	Poor (1) *	Mean Score	Rank
Amaranthus sp.	ACAT seed fair	0 (0)	0 (0)	2 (0.28)	12 (0.85)	1.13	
Amaranthus sp.	Tanzania	0 (0)	0 (0)	2 (0.28)	12 (0.85)	1.13	
Amaranthus sp.	TOT 4151	0 (0)	0 (0)	1 (0.14)	13 (0.92)	1.06	

* Number outside bracket represents number of respondents. Number inside the bracket = sample number of respondents (n)/[the total number of respondents (N) × Likert scale rating].

Table A4. Respondents' evaluation and ranking of *Amaranthus* genotypes according to organoleptic properties (*n* = 14).

Scientific Name	Genotype	Taste					
		Excellent (4) *	Good (3) *	Fair (2) *	Poor (1) *	Mean score	Rank
A. cruentus	AMES-22680	1 (0.28)	12 (2.57)	1.00 (0.14)	0 (0)	2.99	4
A. cruentus	AM-fune	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. cruentus	Anna	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. cruentus	Arusha	2 (0.57)	1 (0.21)	11 (1.57)	0 (0)	2.35	
A. cruentus	Kobie	0 (0)	0 (0)	3 (0.42)	11 (0.78)	1.20	
A. dubius	TOT 8789	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. greacizans	Thohoyandou	0 (0)	4 (0.57)	10 (1.42)	0 (0)	1.99	
A. hybridus	TOT 2266	2 (0.57)	3 (0.64)	2 (0.28)	7 (0.50)	1.99	
A. hybridus	TOT 2358	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. thunbergii	*A. thunbergii*	7 (2)	7 (1.50)	0 (0)	0 (0)	3.5	3
A. tricolor	Tricolor PI462179	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	
A. viridis	W6927N	0 (0)	7 (1.50)	7 (1.00)	0 (0)	2.50	6
Amaranthus sp.	ACAT seed fair	13 (3.71)	1 (0.21)	0 (0)	0 (0)	3.92	1
Amaranthus sp.	Tanzania	10 (2.85)	4 (0.85)	0 (0)	0 (0)	3.70	2
Amaranthus sp.	TOT 4151	0 (0)	7 (1.50)	7 (1.00)	0 (0)	2.50	6
				Aroma			
A. cruentus	AMES-22680	1 (0.28)	12 (2.57)	1 (0.14)	0 (0)	2.99	4
A. cruentus	AM-fune	0 (0)	0 (0)	0 (0)	14 (0.21)	0.21	
A. cruentus	Anna	0 (0)	0 (0)	0 (0)	14 (0.21)	0.21	
A. cruentus	Arusha	2 (0.57)	1 (0.21)	11 (1.57)	0 (0)	2.35	
A. cruentus	Kobie	0 (0)	0 (0)	3 (0.42)	11 (0.78)	1.20	
A. dubius	TOT 8789	0 (0)	0 (0)	0 (0)	14 (0.21)	0.21	
A. greacizans	Thohoyandou	0 (0)	4 (0.85)	10 (2.14)	0 (0)	2.88	5
A. hybridus	TOT 2266	2 (0.57)	3 (0.64)	2 (0.43)	7 (0.50)	2.14	
A. hybridus	TOT 2358	0 (0)	0 (0)	0 (0)	14 (0.21)	0.21	
A. thunbergii	*A. thunbergii*	7 (2.00)	7 (1.50)	0 (0)	0 (0)	3.50	2
A. tricolor	Tricolor PI462179	0 (0)	0 (0)	0 (0)	14 (0.21)	0.21	
A. viridis	W6927N	0 (0)	7 (1.50)	7(1.50)	0 (0)	3.00	3
Amaranthus sp.	ACAT seed fair	13 (3.71)	1 (0.21)	0 (0)	0 (0)	3.92	1
Amaranthus sp.	Tanzania	7 (2.00)	7 (1.50)	0 (0)	0 (0)	3.50	2
Amaranthus sp.	TOT 4151	0 (0)	7 (1.50)	7 (1.5)	0 (0)	3.00	

* Number outside bracket represents number of respondents. Number inside the bracket = sample number of respondents (n)/[the total number of respondents (N) × Likert scale rating].

Table A5. Respondents, evaluation and ranking of *Amaranthus* genotypes according to loss of green colour at seven days after harvesting (n = 14).

Scientific Name	Genotypes	Dark-Green (5) *	Light Green (4) *	Yellowish Green (3) *	Greenish Yellow (2) *	Yellow (1) *	Mean Score	Rank
A. cruentus	AMES-22680	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
A. cruentus	AM-fune	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
A. cruentus	Anna	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
A. cruentus	Arusha	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
A. cruentus	Kobie	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
A. dubius	TOT 8789	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
A. greacizans	Thohoyandou	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
A. hybridus	TOT 2266	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
A. hybridus	TOT 2358	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
A. thunbergii	*A. thunbergii*	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
A. tricolor	Tricolor PI462179	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
A. viridis	W6927N	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
Amaranthus sp.	ACAT seed fair	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
Amaranthus sp.	Tanzania	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1
Amaranthus sp.	TOT 4151	0 (0)	0 (0)	14 (3.00)	0 (0)	0 (0)	3.00	1

* Number outside bracket represents number of respondents. Number inside the bracket = sample number of respondents (n)/[the total number of respondents (N) × Likert scale rating].

Table A6. Respondents' evaluation and ranking of *Amaranthus* genotypes according to wilting at seven days after harvesting (n = 14).

Scientific Name	Genotype	None (5) *	Slight (4) *	Moderate (3) *	Severe (2) *	Extreme (1) *	Mean Score	Rank
A. cruentus	AMES-22680	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3
A. cruentus	AM-fune	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3
A. cruentus	Anna	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3
A. cruentus	Arusha	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3
A. cruentus	Kobie	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3
A. dubius	TOT 8789	0 (0)	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	1
A. greacizans	Thohoyandou	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3
A. hybridus	TOT 2266	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3
A. hybridus	TOT 2358	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3
A. thunbergii	*A. thunbergii*	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3
A. tricolor	Tricolor PI462179	0 (0)	0 (0)	0 (0)	0 (0)	14 (1.00)	1.00	1
A. viridis	W6927N	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3
Amaranthus sp.	ACAT seed fair	0 (0)	0 (0)	0 (0)	13 (1.86)	1 (0.07)	1.93	2
Amaranthus sp.	Tanzania	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3
Amaranthus sp.	TOT 4151	0 (0)	0 (0)	0 (0)	14 (2.00)	0 (0)	2.00	3

* Number outside bracket represents number of respondents. Number inside the bracket = sample number of respondents (n)/[the total number of respondents (N) × Likert scale rating].

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