Participatory Variety Selection of Three African Leafy Vegetables in Western Kenya

Christine Ndinya[1]*, Eunice Onyango[1], Fekadu F. Dinssa[2], Martins Odendo[1], James E. Simon[3,4], Stephen Weller[5], Elias Thuranira[6], Naman Nyabinda[7], Norah Maiyo[7]

[1]Kenya Agricultural and Livestock Research Organization, P. O. Box 169, Code: 50100, Kakamega, Kenya
[2]World Vegetable Centre, Eastern and Southern Africa, P. O. Box 10, Duluti, Arusha, Tanzania
[3]New Use Agriculture and Natural Plant Products Program, Department of Plant Biology, Rutgers University, 59 Dudley Road, New Brunswick, NJ 08901, USA
[4]Center for Agricultural Food Ecosystems, The New Jersey Institute for Food, Nutrition, and Health, Rutgers University, 61 Dudley Road, New Brunswick, NJ 08901, USA
[5]Department of Horticulture & Landscape Architecture, Purdue University, West Lafayette, In, SA
[6]Kenya Agricultural and Livestock Research Organization, P. O. Box 14733, Code: 00800, Nairobi, Kenya
[7]Academic Model Providing Access to Healthcare (AMPATH), P. O. Box 4606, code: 30100, Eldoret, Kenya

*Corresponding author: Christine.omboko@kalro.org, christinendinya@gmail.com

Key words: African nightshade, amaranth, farmer groups, participatory variety selection, spider plant

ABSTRACT

The importance and increasing awareness of African Leafy Vegetables (ALVs) as a rich source of high-quality nutritional food as well as medicinal properties has continued to drive demand by families and consumers. Local ALV land races are low yielding prompting efforts to breed improved high yielding varieties. To enhance the adoption of new ALV varieties, farmers need to be involved in the process. In this study, improved varieties of African nightshade (*Solanum spp.*), amaranth (*Amaranth spp.*) and spider plant (*Cleome gynandra*) were sourced from WorldVeg in Arusha, Tanzania and planted at the Kenya Agricultural and Livestock Research Organization in Alupe agricultural experiment station in a randomized complete block trial and replicated three times. The objectives were to (1) determine farmer criteria for selecting ALVs, and (2) to evaluate and select farmers preferred improved varieties of African nightshade, amaranth and spider plant for possible release and commercial seed production. Thirty-two farmers, 28 women and 4 men from ALV producing farmer groups in Busia, Kisumu and Nandi Counties participated in ALV variety selection at Alupe Research Centre. These farmer groups were contributors to the implementation of the HORT Innovation project sponsored by USAID. The appointed farmers completed the preference questionnaires as guided by researchers during the in-person field evaluations. The results of the study indicated that seed viability and germination, yield, leaf color, resistance to pest and diseases were the most important criteria concern by the farmers while selecting the varieties of ALVs. The top three varieties selected by the farmers from each of the three vegetables species were African nightshade (BG-29, SS-52, commercial), amaranth (commercial, AC-45, Ex-Zim) and spider plant (UG-15, commercial, UG-23). Three selected varieties from WorldVeg Ex-Zim, Nduruma, SF-29, and AC 38 were given to farmers for community seed production and were also tested for distinctiveness, uniformity and stability by the national seed regulator and released for commercial seed production by the Kenyan Ministry of Agriculture in 2018.

INTRODUCTION

African leafy vegetables (ALVs) commonly grown and consumed in western Kenya include spider plant (*Cleome gynandra*), African nightshade

(*Solanum spp.*), cowpea (*Vigna Unguiculata*), amaranth (*Amaranthus spp.*), slender leaf (*Crotolaria brevidens*) and jute mallow (*Cochorus olitorius*). Most of these vegetables have been collected and harvested from the wild for many years. The situation has now changed and domestication of these vegetables is more common although most are still found in the wild. The shift to domestication has been contributed by a decline in habitats with wild grown vegetables and an increased demand of ALVs because of the benefits that include, medicinal properties (Eteka et al., 2010, Okole et al., 2014) and high nutrient contents of vitamins, minerals and proteins (Byrnes et al., 2017, McBurney et al. 2004, Weller et al., 2015, Yang et al 2013). Increased sales have been noted in supermarkets, local markets, restaurants and urban markets (Shiundu and Oniang'o, 2007). The shortage of these vegetables is quite common during the dry season from November to February.

In local village markets, most available ALVs are usually local land races that mature early, often have small leaves, and provide low yields (Ojiewo et al, 2013). However, with increased demand and different customers' preferences, suppliers need increased production and want more product choices.

Younger consumers prefer ALVs that are not bitter in flavor and the modern working women want types with larger leaves that are easier to prepare. These preferences have made some varieties, especially those that are improved, to become more popular than others (Croft et al., 2014). To increase ALV production and meet the different needs of consumers, more efforts are being made to increase the number of improved varieties available for farmers to grow (Sogbohossou et al., 2018, Ronoh et al., 2018).

The approach to disseminating new varieties has changed. When ALV plant breeders unilaterally select varieties without input from farmers, farmers' adoption is slow because ultimately farmers will adopt or choose not to adopt a new variety following their assessment of its field performance, ease of seed collection and even cost of the seed. Many varieties have been developed but farmers still prefer growing the older varieties (Kolech et al., 2017). Farmers' involvement in selection will hasten the adoption of new varieties. Therefore, farmers are now engaged in the breeding process or select from developed varieties using the participatory variety evaluation and selection (PVS) approach. This approach can be very efficient for the plant breeder, the seed company and the farmer and the community. PVS is the selection by farmers of preferred varieties of advance material from plant breeding products. PVS is used to identify varieties that can be multiplied quickly by the formal seed sector (Joshi and Witcomb, 1998). The importance of farmer involvement in variety evaluation and selection helps breeders understand farmers' preferences across communities. The objectives of this study were to determine the criteria farmers use in selecting ALV varieties and identify the varieties they prefer for commercial development. The ultimate goal was to provide an informed basis for choosing varieties that have potential for the official release and likelihood to be adopted for production to increase the availability of ALVs in high demand.

MATERIALS AND METHODS

Study area.

The study was conducted at the Kenya Agricultural and Livestock Research Organization (KALRO) Alupe research centre in Busia County, in the western part of Kenya bordering Uganda; 5 km from Busia. The elevation is 1,227metres above sea level where, temperatures range between 22^0C-30^0C and rainfall is bimodal with an annual average of 900-1500 mm. The starting dates of the rain although increasingly unpredictable is usually late March or early April. Soils in Alupe are not fertile, they are the laterite type, frequently found in Busia County (Odendo et al., 2001). Laterite soils in the classification system are the most highly weathered soils, they are red in color, rich in iron and aluminum and commonly found in the tropics (Tzu-Hsing, 2014).

A selection of improved varieties of African nightshade (6), amaranth (7) and spider plant (5) (Table 1) were sourced from WorldVeg and planted in April 2017 as researcher managed evaluation trials. The randomized complete block design replicated three times was used for the trials. Local land races and released commercial varieties from Kenya Seed Company (Simlaw Seeds) were included as controls. The Simlaw vegetables have the general local names for but not specific variety names. First, land was plowed with a tractor and harrowed. Di-ammonium phosphate fertilizer was applied at a rate of 50 kg per hectare. Seeds of the vegetables were planted by drilling and after two weeks, thinning was done at the spacing of 25 cm by 50 cm for spider plant and amaranth and 40 cm by 50 cm for African nightshade. The vegetables were rain fed and not irrigated.

After two months, when the leafy vegetables were at their peak vegetative stages, a total of 32 farmers (28 women and 4 men) from Busia, Kisumu and Nandi counties were invited to visit the research centre to evaluate and prioritize their preferred varieties. The farmer composition was made up of farmer groups growing vegetables. Those below 30 years old were 3 men and 13 women. One man and 13 women were above 30 years old. The youngest male and female participants were 17 and 18 years respectively. The oldest man was 65 years and the oldest woman 47 years. Participating farmers were appointed by their respective farmer group members.

Three lists of important characteristics for spider plant, African nightshade and Amaranth vegetables selection were developed in focus group discussions with farmers in previous meetings. Farmers were asked to list important traits in selection of the three ALV species. The criteria for variety selection jointly agreed upon by the farmers and researchers included size and color of leaves; plant size, maturity period and pest and disease tolerance.

Data collection and analysis.

Farmers were given questionnaires and guidance on how to complete them. They were divided into three groups to avoid overcrowding. Each group included a member of the research team to provide support. A group scored a single vegetable species before moving to the next. Farmers, who were illiterate, were helped with the writing. The questionnaire had a table with 80 slots for writing scores and 4 additional question on selection of the ALV varieties. Farmers filled the questionnaires as individuals as discussing responses among them was discouraged. Therefore, scoring and ranking were done by farmers. The assessment was based on each individual farmer's perception. The way farmers classify and value traits can vary between sex and households in a community, and affects the adoption and abandonment of varieties and populations (Soleri, 2004). Matrix ranking was applied during the variety selection. Respondents evaluated the varieties using a five-point reference scale of 1 to 5 (1=very bad, 2=bad, 3=Average, 4=good, 5=very good). Scoring was done from only one replication (Rep no. 1) of the trial for each species because visually, each of the replications appeared uniform and varieties appeared to perform in same way across the replications and to make it more acceptable to the participating farmers. The one-page matrix sheet had the list of criteria for evaluation and plot numbers for which they were scoring (awarding marks). Farmers first scored for individual criteria against each variety, next they gave an overall score for each variety using the scale of 1 to 5 then they ranked the varieties from the first to the last (1…n) and finally wrote reasons for picking the first three and last choice. Examples of guidelines given to farmers for ALV evaluation are shown in Table 2. Score of 1 was for the least preferred and 5 the most preferred. Time of completion of the questionnaires varied among the farmers ranging from 30-45 minutes. Before the evaluation of vegetables farmers wrote their personal details at the top of the for name, sex, age, education level and county of residence.

Data collected were entered into an Excel spreadsheet. The data were subjected to statistical analyses using the Statistical Package for Social Sciences (SPSS). A Five-point Likert scale (very poor, poor, average, good and very good) was used to analyze data collected and summarized as mean scores for varietal characteristics that included maturity, number of branches, leaf size, leaf color, germination, leaf yield and marketability. Analysis of variance was used to evaluate the significance difference between mean scores also at a p-value of 5 %.

RESULTS

All farmers were involved in evaluating all the crops with the following exceptions: Amaranth (3 of 4 men) and spider plant (27 of 28 women). The criteria and traits farmers listed as priorities for accepting varieties are shown in Table 3. Green leaf color, broad leaves and good germination as measured by double digit percentages at 18.8, 16.7 and 12.5 percent respectively, were the top priorities for African nightshade varieties. In amaranth high yields; (20.9%, and green leaf color (14%) were the top criteria. Good germination (16.75) resistance to pests and diseases (14.3), broad leaves (11.9%) and high yields (11.9%) were top priorities for spider plant varieties

Criteria identified by farmers for rejecting African nightshade, spider plant and amaranth are listed in (Table 4). of the 8 noted for African nightshade, poor germination (42.9%), small leaves (14.3%) and bitter leaves (11.5%) topped the list. For amaranth, varieties poor germination (38.7) and pest and disease infestation (12.9) were most important while for spider plant varieties poor germination (45.5%) and pest and disease infestation (15.2%) were the main concern.

Farmers' scores for individual varieties against criteria selected are shown in Tables 5, 6 and 7. Overall preference ranking of the African nightshade varieties by farmers is shown in Table 8. The variety of BG-29 had a mean score (4.43) that was significantly higher than the rest. Just below SS-52, the commercial variety and Nduruma all had relatively high mean scores of 4.32, 4.14 and 4.05 respectively, that were not significantly different from each other. The lowest score (2.61) was for a local land race that is bitter, is small in size with small leaves and very susceptible to Fusarium wilt.

Table 9 shows the commercial variety and WorldVeg varieties AC-45 and Ex-Zim with the highest mean scores of 4.10, 4.05 and 4.00 respectively. None were significantly different from each other. The local land race means score (1.73) was significantly lower than for all the other amaranth varieties. The top three spider plant mean scores were for UG-SF-15 (4.00), the commercial variety (3.80) and UG-SF-23 (3.71). However, the scores were not significantly different (Table 10). The local land race, PS and ML-SF-17 had the least mean scores of 2.38, 2.67 and 2.76 respectively. From the farmers' perspective, PS and ML-SF-17 were not better than the local landrace.

DISCUSSION

Criteria used by a higher percentage of farmers to choose varieties regardless of the crop were green leaf color, broad leaves, high yields and pest and disease resistance and germination. Color often reflects the health of a plant. Yellow-colored leaves in African nightshade, amaranth and spider plant are symptoms of the disorder such as nutrient deficiency or disease and pest attack. However amaranth varieties such as AM-40 have red/purple leaves, others have leaves that are yellow, maroon or variegated colored because of genetic makeup. Amaranthus has a wide genetic diversity 60-75 species of which 17 are edible and three are grain species (Nguyen et al., 2019). A study of 6 Amaranthus species indicated that variation existed in the genetic diversity of different populations (Ray et al., 2008)

Presumably farmers determined the yield potential of varieties by observing the number, sizes and shapes and vigor of plants. Experts estimate yield by assessing crop colour, plant vigor and plant density in the field using the eye assessment method (Sapkota et al., 2020) which requires practical and technical familiarity.

Pests and diseases tolerance were determined by their presence or absence and the amount of damage symptoms on the plants. Pest and diseases tolerance were very important to farmers. Previous studies (Maseko et al, 2018) state that ALVs are often tolerant to diseases and pests because they have adapted to the local environment, but this may change with new varieties that target only yield increase without consideration of pest/disease resistance. The emergence of new pests and diseases is a reality for many crops including well-studied staples like maize, because of climate change. Climate change creates new ecological niches enabling the emergence of new plant diseases and pests. (FAO, 2008). To date, very little research has been done on traditional ALVs in sub-Saharan Africa in the area of pests and diseases and as more research is done on increasing yield by developing faster- growing crops, researchers may unintentionally remove pest and disease resistance traits that made these plants so adaptable to their environment (Cernasky, 2015). When varieties are not tolerant to pests and diseases many challenges can emerge. Starting with uninformed use of chemical pesticides that invariably leads to many other problems. Some identified ALV pests include aphids, spider mites early blight (*Alternaria solani*), late blight (*Phytophthora infestans*), Anthracnose (*Collectotrichum atramentarium*) Mosaic virus-CMV, TMV, ToMVin African nightshade; Canker (*Clavibacter michiganensis),* Bacterial wilt (*Ralstonia, solanacearum*, Black rot (*Xanthhomonas campestris*) in Amaranth; Wet rot *(Choanephora cucurbitarum),* Fusarium wilt, root rot *(Fusarium oxysporum)* in spider plant (Abang et al. 2016). Farmers are encouraged to employ crop rotation as part of their overall integrated pest management program though when their acreage is so limited in size the practicality of this is challenging and often can be employed by altering crops grown over different seasons.

Good germination was another important farmer criterion in the selection of African nightshade and spider plant varieties. Yet, farmers' ability to meet the increasing demand for these vegetables has been limited by a lack of good quality seed (Kansime et al., 2016). Germination rate can be a varietal trait but also depends on seed quality management during crop production, processing and storage. Therefore, poor germination can also be caused by poor management of seed. The seed processing method determines the seed quality (Louwaars and De Boef 2012). Farmers can determine if germination is good by noting the population of plants in a plot. Germination inability may be tagged to a variety if it is susceptible to seed or soil-borne diseases that affect the ability of seed to emerge. An example of such a variety is the local land race of African nightshade used in this study whose seedling dies early resulting to low populations.

Farmers personal experience with poor germination of ALV seeds made this trait particularly important in the selection of varieties. Poor quality seed contributes to low yields; for example, in Kenya, nightshade leaves can yield 30 tones, but farmers produce less than 2 tones per ha because lack of knowledge on the processing of nightshade has led to poor seed stocks. (Kimaru et al., 2019). Part of this experience come from their use of land races. Ateka *et al*. (2014) state that seeds from wild species generally display a high level of dormancy that is often the source of seed for these farmers. Germination tests of farmers' and researchers' seeds of African nightshade, spider plant and Amaranth were 5%, 15% and 70 % respectively for farmers' samples and 50%, 65% and 80% for researchers' samples (Oluoch et al., 2009). The main source of ALV seed is from the local informal market whereby the quality of seed cannot be guaranteed. Seed demand analysis of ALVs by farmers from local market sources in 2018 was estimated at 32 tons per year, against the formal supply of 4.4 tons (Kansime et al., 2018). The environment in which these vegetables were grown and where the farmers hailed from is ideal for good seed germination. Temperatures in Alupe-Busia range from 22^0C-30^0C within the optimum for the germination of most ALVs. (Motsa et al., 2015).

Characteristics that contributed to the rejection of varieties by many farmers were first and foremost poor germination, for all the three vegetables followed by susceptibility to pests and diseases as a distant second for amaranth and spider plant., and small leaf size for African nightshade. This study shows that farmers main concern is the germination rate of a seed. If germination is low this translates to a low plant population and eventually low production. Late maturity as a criterion for rejecting a variety was chosen by only 2.9 % of the farmers. While a late-maturing ALV crop may not be ideal for a food security. It does have the advantages of a steady harvest once mature compared to a cereal where the entire harvest would be delayed.

In the actual scoring, Ex-Zan an amaranth variety, was given scores for either bad or very bad in all the criteria. The local variety of spider plant was given scores for bad in the criteria; farmers gave the rest of the varieties good or very good scores. This implies that apart form 2 farmers liked the rest of varieties under evaluation. Evaluation and selection may also be influenced by the immediate market demand where the farmers sell their vegetables and they may not realize that some vegetables can end up in large cities in Nairobi and Mombasa where customer preference may differ (Croft et al, 2014).

CONCLUSION

Farmers prefer varieties that are high yielding. Consequently, plant traits that are indicative of high yield are important criteria for farmers in variety selection. This includes large number and sizes of leaves as well as large plants. Tolerance to pests and disease is an important trait used by farmers in selecting varieties. Although not a direct yield trait, it is an indicative of the ability of a variety to give good yields. Therefore, farmers' perceptions regarding pests and diseases of ALVs and associated crop protection should be a key element in developing research proposals that will aim not only for high yield but also safe food and clean environment (Okolle *et al.*2014). Germination rates also were important to farmers.

Among the varieties that scored highly with the farmers, Ex-Zim, AC-38, Nduruma, Ex-Hai, ML-SF-29 were tested for distinctiveness, uniformity and stability with Kenya Plant Health Inspectorate services, and were officially released by the Kenya government through the Ministry of Agriculture for commercial seed production in 2018. Our expectation is that seed availability of these ALV varieties will improve and subsequent vegetable production will increase.

Table 1: African leafy vegetable varieties sourced from WorldVeg for trials at KALRO Alupe,

No.	African nightshade	Species	Amaranth	Species	Spider plant	Species
1	Nduruma (BG-16)	*S. scrabrum*	EX-ZAN	*Amaranthus spp.*	MLSF-17	*C. Gynandra*
2	Ex-Hai	*S. scrabrum*	UG-AM-40	*Amaranthus spp.*	UG-SF-15	*C. Gynandra*
3	Olevolosi (SS-49)	*S. scrabrum*	AC-45	*Amaranthus spp.*	UG-SF-23	*C. Gynandra*
4	SS-04-2	*S. scrabrum*	AC-NL	*A. cruentus*	ML-SF-29	*C. Gynandra*
5	SS-52	*S. scrabrum*	Ex-Zim	*A.cruentus*	PS	*C. Gynandra*
6	BG-29	*S. scrabrum*	AC-38	*A. cruentus*	commercial	*C. Gynandra*
7	commercial	S. scrabrum	AH-TL-Sel	*A.hypochondriacus*	local	*C. Gynandra*
8	Local	S. villosum	Local	*Amaranthus spp.*		
9			commercial	*A.Lividus*		

Table 2: Examples of guidelines given to farmers for scoring during ALV evaluation.

Criteria	Description
Maturity	5-All Plants flowering; 4-all plants ready for leaf harvesting; 3-most plants ready for harvesting; 2-few plants ready for harvested; 1-no plants ready for harvesting
Leaf colour	5- l dark green leaves: 4-green leaves 3: light green leaves 2-yellowish ;1- leaf variegated or red
Leaf sizes	5-Very large leave sizes; 2-Large leave sizes; 3-Moderate leaf sizes; 2-small leaf sizes: 1-very small leave sizes
Good germination	5-100% emergence: 4-80-70 % emergence: 3. 50-60% emergence 40-30 % emergence, 0-20 % emergence
Pest and diseases tolerance	5-healthy clean plants with no infections 4-slightly diseased plants 3- diseased plants 2 diseased but no deaths:1-severe disease and death of plants
Taste	5-no bitterness; 2;v. slight bitterness 3; bitter 4very bitter 5;v. very bitter
Hairiness	5-smooth 4-slighly hairy 3-moderately 2-hairy 1-very hairy y

Table 3: Farmers criteria for accepting a variety as a percentage of farmers choosing the trait.

Criteria for approval of variety	African nightshade (N=32)	Amaranth (N=31)	Spider plant (N=30)
		% of farmers	
High yields	4.2	20.9	11.9
Green leaves	18.8	14.0	4.8
Broad leaves	16.7	9.3	11.9
Early maturity	6.8	9.3	9.5
Good germination	12.5	9.3	16.7
Many branches	6.3	9.3	9.5
Highly vegetative	4.2	4.7	4.8
Resistant to pests & diseases	4 .2	2.3	14.3
Short enough	NA	2.3	NA
Not bitter	6.3	2.3	2.4
Liked by many	2.1	NA	NA
Not hairy	NA	NA	2.4

Percentage of farmers and criteria of choice for selecting the three ALVs. A low score indicates that the characteristic is less important. NA=not a criterion for this crop

Table 4: Farmers criteria for rejecting a variety as a percentage of farmers choosing the trait.

Criteria for rejection of variety	African nightshade (N=32)	Amaranth (N=31)	Spider plant (N=30)
		% of farmers	
Poor germination	42.9	38.7	45.5
Pests & diseases infestation	8.6	12.9	15.2
Low yields	8.6	6.5	9.1
Stunted growth	NA	6.5	NA
Bad color	NA	3.2	NA
Late maturity	2.9	3.2	3.0
Less leaves	NA	3.2	NA
Low germination	NA	3.2	NA
Small leaves	14.3	3.2	9.1
Yellow leaves	NA	3.2	3.0
Bitter leaves	11.5	6.5	NA
Few branches	5.8	NA	NA
Too tall	2.9	NA	3.0
Hairy	NA	NA	3.0

Percentage of farmers and criteria of choice for rejecting varieties of the three ALVs. A low score indicates that the characteristic is less important. NA=not a criterion for this crop

Table 5: Farmers evaluation of Amaranth varieties using selected criteria.

criterion	Ranking	Ex-Zan	UG-AM-40	AC-45	AC-NL	Ex-Zim	AC-38	AH-TL-Sel	Local	commercial
		Scale								
Maturity	mean	1.6	3.1	3.7	4.0	3.5	3.6	3.5	3.9	4.0
	median	1.0	3.0	4.0	4.0	4.0	4.0	3.5	4.0	4.0
branches	mean	1.6	3.2	3.6	4.3	4.1	3.7	3.2	4.0	3.3
	median	1.5	3.0	4.0	5.0	4.0	4.0	3.0	4.0	3.0
Leaf size	mean	1.6	3.6	3.3	4.0	4.1	4.1	3.3	3.9	3.7
	median	2.0	4.0	3.5	4.0	4.0	4.0	3.0	4.0	4.0
Leaf colour	mean	1.8	3.5	2.5	4.0	4.1	3.9	3.3	3.6	4.0
	median	2.0	4.0	2.0	4.0	4.0	4.0	3.0	4.0	4.0
Pests and diseases	mean	1.5	3.0	3.8	4.0	4.1	3.8	3.6	3.7	3.8
	median	1.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
germination	mean	1.5	2.9	3.9	4.3	2.4	4.2	4.0	3.0	4.3
	median	1.0	3.0	4.0	5.0	2.0	4.0	4.0	3.0	5.0
Marketability	mean	1.8	3.5	2.2	4.2	3.9	4.0	3.5	3.3	3.9
	median	2.0	4.0	2.0	4.0	4.0	4.0	3.3	3.0	4.0
Leaf yield	mean	1.7	3.2	3.1	4.1	3.8	4.0	3.3	3.4	3.7
	median	2.0	3.0	3.0	4.0	4.8	4.0	3.0	3.5	4.0

Scale of 1 to 5 (1=very bad, 2=bad, 3=Average, 4=good, 5=very good).

Table 6: Farmers evaluation of African nightshade varieties using selected criteria.

criterion	Ranking	Nduruma (BG-16)	Ex-Hai	Olevolosi (SS-49)	SS-04-2	SS-52	BG-29	Commercial	local
		Scale							
Maturity	mean	2.8	3.5	3.3	3.5	4.2	3.4	4.2	4.3
	median	3.0	4.0	3.0	4.0	4.0	3.0	4.4	5.0
branches	mean	3.2	3.8	3.9	3.6	4.3	3.9	4.1	4.3
	median	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Leaf size	mean	3.1	4.2	3.6	4.2	4.3	2.8	4.0	3.9
	median	3.0	5.0	4.0	4.0	4.0	3.0	4.0	4.0
Leaf colour	mean	3.8	4.2	3.7	4.1	4.2	3.7	3.9	4.1
	median	4.0	5.0	4.0	4.0	4.0	4.0	4.0	4.1
Pests and diseases	mean	3.4	3.9	4.2	3.6	3.4	3.7	3.9	4.4
	median	4.0	4.0	5.0	3.0	3.0	4.0	4.0	5.0
germination	mean	3.8	3.8	3.6	3.0	3.5	3.5	4.0	4.4
	median	4.0	4.0	4.0	3.0	3.0	4.0	4.0	5.0
Marketability	mean	4.2	4.2	3.5	4.1	4.3	3.3	4.0	4.1
	median	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Leaf yield	mean	4.0	3.3	3.3	4.0	4.1	3.2	3.9	3.9
	median	4.0	3.0	3.0	4.0	4.0	3.0	4.0	4.0

scale of 1 to 5 (1=very bad, 2=bad, 3=Average, 4=good, 5=very good)

Table 7: Farmers evaluation of spider plant varieties using selected criteria.

criterion	ranking	ML-SF-17	UG-SF-15	UG-SF-23	ML-SF-29	PS	Commercial	Local
		Scale						
Maturity	mean	3.0	3.8	3.7	3.5	3.6	3.0	2.6
	median	3.0	4.0	4.0	4.0	3.5	3.0	3.0
branches	mean	2.9	3.7	3.9	3.8	3.6	2.5	2.2
	median	3.0	4.0	4.0	4.0	4.0	2.0	2.0
Leaf size	mean	3.0	3.3	3.6	3.8	3.6	2.6	2.8
	median	3.0	3.5	4.0	4.0	4.0	3.0	3.0
Leaf colour	mean	3.1	3.7	3.8	3.6	3.6	3.3	2.9
	median	3.0	4.0	4.0	3.5	4.0	3.0	3.0
Pests and diseases	mean	3.1	3.8	3.3	3.6	3.6	3.1	2.4
	median	4.0	4.0	4.0	4.0	4.0	3.0	2.0
germination	mean	2.4	4.1	4.1	3.7	3.8	2.9	2.1
	median	2.0	4.0	4.0	4.0	4.0	3.0	2.0
Marketability	mean	3.1	3.7	3.5	3.6	3.9	2.5	2.4
	median	3.0	4.0	4.0	4.0	4.0	2.0	2.0
Leaf yield	mean	3.0	3.6	3.6	3.6	3.9	2.9	2.3
	median	3.0	4.0	4.0	4.0	4.0	3.0	2.0

Scale of 1 to 5 (1=very bad, 2=bad, 3=Average, 4=good, 5=very good)

Table 8: African nightshade varieties preferred by farmers.

Variety	Overall mean Score out of 5
BG-29	4.43[a]
SS-52	4.32[ab]
Commercial	4.14[abc]
Nduruma	4.05[abc]
Ex-Hai	3.91[abc]
SS-04-2	3.81[bc]
Olevolosi	3.67[c]
Local seed	2.61[d]
Mean	3.86
LSD (0.01)	0.59
CV%	25.4

Low scores indicate varieties are less preferred. Means followed by the same letter are not significantly different and therefore the characteristics were ranked the same.
CV is the ratio of standard deviation to the mean,
LSD indicates least significant difference between the means at the required level of probability (P≤0.0
LSD= $t_{0.05}$ x sqrt(2xEMS/n)
Where; EMS – Error mean square from the ANOVA table
n – No. of observations

Table 9: Amaranth varieties preferred by farmers.

Variety	Overall mean Score out of 5
Commercial	4.10[a]
AC-45	4.05[a]
Ex-Zim	4.00[a]
AC-NL	3.59[ab]
AC-38	3.57[abc]
AH-TL-Sei	3.38[bc]
Ex-Zan	3.18[bc]
UG-AM-40	3.00[c]
Local seed	1.73[d]
Mean	3.39
LSD (0.01)	0.59
CV%	28.9

Low scores indicate varieties that are less preferred. Means followed by the same letter are not significantly different and therefore the characteristics were ranked the same
CV is the ratio of standard deviation to the mean,
LSD indicates least significant difference between the means at the required level of probability ($P \leq 0.0$
LSD= $t_{0.05}$ x sqrt(2xEMS/n)
Where; EMS – Error mean square from the ANOVA table
n – No. of observations

Table 10: Spider plant varieties preferred by farmers.

Variety	Overall Mean Score out of 5
UG-SF-15	4.00[a]
Commercial	3.80[a]
UG-SF-23	3.71[a]
ML-SF-29	3.70[a]
ML-SF-17	2.76[b]
PS	2.67[b]
Local land race	2.38[b]
Mean	3.20
LSD (0.01)	0.72
CV%	34.5

Low scores indicate varieties that are less preferred. Means followed by the same letter are not significantly different and therefore the characteristics were ranked the same.
CV is the ratio of standard deviation to the mean
LSD indicates least significant difference between the means at the required level of probability ($P \leq 0.0$)
LSD= $t_{0.05}$ x sqrt(2xEMS/n)
Where; EMS – Error mean square from the ANOVA table
n – No. of observations

ACKNOWLEDGMENTS

This research was supported by the Horticulture Innovation Lab with funding from the U.S. Agency for International Development (USAID EPA-A-00-09- 00004), as part of the U.S. Government's global hunger and food security initiative, Feed the Future, for project titled ‘‘Improving nutrition with African indigenous vegetables’’ in eastern Africa. The contents are the responsibility of the Horticulture Innovation Lab and do not necessarily reflect the views of USAID or the United States Government. We also thank the Director General KALRO for their General Support in this and other African traditional crops research.

REFERENCES

Abang, M.M., Kihurani, A.W., and Srinivasan R., 2016. Managing Diseases and Pests of Indigenous Vegetables for GAP Compliance in Sub-Saharan Africa. https//w.w.w.researchgate.net/publications/235322304. Accessed 7th September 2020

Byrnes, D.R., Dinssa, F.F., Weller, S.C., and Simon, J.E. 2017. Elemental micronutrient content and horticultural performance of various vegetable Amaranth genotypes. J. Amer. Soc. Hort. Sci. 142(4):265-271.DOI: 10.21273/JASHS04064-17.

Cernansky R. 2015. The rise of Africa's super vegetables. Nature 522:146–148.

Croft, M.M., Marshall, M.I., and Weller S.C. 2014. Consumers' preference for quality in three African indigenous vegetables in Western Kenya. Journal of Agricultural Economics and Development 3(5):067-077,

Etèka, C.A., Ahohuendo, B.C., Ahoton, L.E., Dabadé S.D., and Ahanchédé A. 2010. Seeds' germination of four traditional leafy vegetables in Benin (LFT). Tropicultura, 28(3):148-152.

FAO, 2008 Climate-Related Transboundary Pests and Diseases Technical Background Document From the Expert Consultation Held on 25 to 27 February 2008 FAO, Rome. http://www.fao.org/3/a-ai785e.pdf accessed 6th September 2020.

Joshi A., Witcombe J.R. 1998. Farmer Participatory Approaches for Varietal Improvement DOI: https://www.developmentbookshelf.com/doi/abs/10.3362/9781780445854.012 10.3362/9781780445854012

Kansiime, M., Nicodemus, J., Kessy, R.F., Afari-sefa, V., Marandu, D., Samali, S., Swarbrick, P., Romney, D., Karanja, D. 2016. Good seed for quality produce: indigenous vegetables boost farmer incomes and livelihoods in Tanzania. CABI impact case study 17, 8pp.DOI: 10.1079/CABICOMM-47-495

Kansiime, M., Karanja, D., Alokit C., and Ochieng J. 2018. Derived demand for African indigenous vegetable seed: Implications for farmer-seed entrepreneurship development International Food and Agribusiness Management Association 21(6):1-17 DOI: 10.22434/IFAMR2017.0095

Kimaru, S.L., Kilalo, D., Kimenju, J.W., and Muiru W. M. 2019. Evaluation of a suitable seed processing method for increased production of edible nightshade (*Solanum scabrum*) leafy vegetable, Cogent Food & Agriculture, 5(1):1659212 https://doi.org/10.1080/23311932.2019.1659212

Kolech, S.A., De Jong, W., Perry, K., Halseth, D., Mengistu, F., 2017. Participatory variety selection: A tool to understand farmers' potato variety selection criteria open agriculture. 2:453–463.

Louwaars, N.P., and De Boef, W.S. 2012. Integrated seed sector development in Africa: A conceptual frame-work for creating coherence between practices, programs, and policies. Journal of Crop Improvement 26:39–59. doi:10.1080/15427528.2011.611277

Maseko, I., Mabhaudhi, T., Tesfay, S., Tesfamicael, H. A., Fezzehazion, M., and Du Plooy, C.P., 2017. African leafy vegetables: a review of status, production and utilization in South Africa. Sustainability 2018, 10:16; doi:10.3390/su10010016

McBurney, R.P.H., Griffin, C., Paul, A.A., and Greenberg, D.C., 2004. The nutritional composition of African wild food plants: From compilation to utilization. Journal of Food Composition and Analysis 17:277–289.

Motsa, M.M., Slabbert M.M, van Averbeke W., and Morey L., 2015. Effect of light and temperature on seed germination of selected African leafy vegetables. South African Journal of Botany 99:29–35.

Nguyen, D.C., Tran, D.S., Tran, T.T.H., Ohsawa, R., and Yoshioka, Y., 2019. Genetic diversity of leafy amaranth (*Amaranthus tricolor* L.) resources in Vietnam Breeding Science 69:640–650. doi:10.1270/jsbbs.19050

Odendo, M., De Groote, H., and Odongo, O.M. 2001. Assessment of Farmers' Preferences and Constraints to Maize Production in Moist Mid-Altitude Zone of Western Kenya. Paper presented at the fifth International Conference of the African Crop Science Society, Lagos, Nigeria October 21-26, 2001.

Oluoch M., Pichop, G.N., Silué, D., Abukutsa-Onyango, M.O., Diouf, M., and Shackleton C.M. 2009. Production and Harvesting Systems for African Indigenous vegetables. https://www.researchgate.net/publication/263366224.

Ojiewo, C.O., Mbwambo, O., Swai, I., Samali, S., Tilya M.S., Mnzava, R.N., Mrosso, L., Minja R., and Oluoch, M., 2013. Selection, evaluation and release of varieties from genetically diverse African nightshade germplasm. International Journal of Plant Breeding 7(2):76-89.

Okolle, J.N., Ijiang, P.T., and Ngome, J.A. 2014. Evaluation of Farmer's Knowledge on Pests and Diseases of Vegetables and Their Management Practices in Three Different Agro-ecological Zones in Cameroon.
https://humidtropics.cgiar.org/.../Cameroon%20Crop%20protect%20study%20Report

Ray, T., and Roy S.C. 2009. Genetic diversity of *Amaranthus* species from the Indo-Gangetic plains revealed by RAPD analysis deading to the development of ecotype-specific SCAR Marker Journal of Heredity 100(3):338–347. doi:10.1093/jhered/esn102

Ronoh, R., Ekhuya, N.A., Linde, M., Winkelmann, T., Abukutsa-Onyango, M., Dinssa, F.F and Debener, T. 2018. African nightshades: genetic, biochemical and metabolite diversity of an underutilized indigenous leafy vegetable and its potential for plant breeding. Journal of Horticultural Science and Biotechnology 93(2):113-121, DOI: 10.1080/14620316.2017.1358112

Tek, S.B., Jat, M.L., Jat, R.K., Kapoor, P., and Stirling C. Yield Estimation of Food and non-Food Crops in small-holder production systems. https://samples.ccafs.cgiar.org/measurement-methods/chapter-8-yield-estimation-of-food-and-non-food-crops-in-smallholder-production-systems/

Tzu-Hsing, Ko., 2014. Nature and properties of lateritic soils derived from different parent materials in Taiwan. The Scientific World Journal vol. 2014, Article ID 247194, 4 pages. https://doi.org/10.1155/2014/247194

Shiundu, K.M., and Oniang'o, R., 2007. Marketing African leafy vegetables: challenges and opportunities in the Kenyan context. African Journal of Food, Agriculture, Nutrition and Development (ISSN: 1684-5358) Vol 7(4):2007.

Sogbohossou, D.E.O., Achigan-Dako, E.G., Maundu P., Solberg S., Deguenon E.M.S., Mumm R.H., Hale, I., Van Deynze A., and Schranz, M.E. 2018. A roadmap for breeding orphan leafy vegetable species: a case study of *Gynandropsis gynandra* (Cleomaceae). Horticulture Research 5:2 DOI 10.1038/s41438-017-0001-2

Soleri, D., and David, A., 2004. Farmer Selection and Conservation of Crop Varieties. citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.410.6608&rep=rep1

Weller, S.C., Van Wyk E. and J.E. Simon, J.E. 2015. Sustainable production for more resilient food production systems: Case study of African Indigenous Vegetables in Eastern Africa. International Horticultural Congress, Brisbane, Australia. Acta Horticulturae 1102:289-298.

Yang, R.Y., Fischer, S., Hanson P.M., and Keatinge J.D.H. 2013. Increasing micronutrient availability from food in sub-Saharan Africa with indigenous vegetables, pp. 231-254. In: Juliani, H.R., J.E. Simon and C.T. Ho (eds). African Natural Plant Products: Discoveries and Challenges in Chemistry, Health and Nutrition. American Chemical Society Symposium Series 1021. American Chemical Society, Washington, D.C. USA.