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Farmers' Integrated Evaluation of Elite Orange-Fleshed Sweetpotato Genotypes in Diverse Agro Ecological Areas of Ethiopia

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Abstract

Six orange-fleshed sweetpotato genotypes were evaluated in integration with farmers in 2022 to identify their preferred varieties for enhanced production. A mother trial was conducted in a randomized complete block design across five locations: Hawassa, Halaba, Wondogenet, Arbaminch, and Fogera. A baby trial was set up with about 150 farmers. Each farmer got 200 cuttings from one new genotype and two released varieties. Data on yield and yield-related traits were recorded from the mother trial, including organoleptic aspects of boiled roots, and subjected to analysis of variance. Significant differences ($p<0.05$) were observed for all traits considered. G3 (13NC9350A-9-3) had the highest root yield of 26.83 t/ha, while G4 (105413-5) had the lowest root yield of 12.20 t/ha. The highest and lowest above-ground biomass yields were recorded for G4 (105413-5) and G5 (Alamura) 37.33 to 20.54 t/ha, respectively. The significant differences observed among genotypes in sweetpotato virus disease (SPVD) reactions. G1 (MUSG014052-51-24) and G3 (13NC9350A-9-3) showed the highest and lowest scores of 3.8 and 2.0 for SPVD, respectively, reflecting scores <3.0 and >3.0, which indicate tolerance and susceptibility to SPVD, respectively. Farmers' criteria included agronomic traits like drought tolerance, earliness (time to harvest), high root yield, SPVD tolerance, and vegetative performance, as well as organoleptic qualities of boiled roots: mealiness, taste, color, hardness, and odor. Considering all these traits, Alamura, 13NC9350A-9-3, and Kabode emerged as the top three genotypes selected by farmers. Therefore, these genotypes are recommended for scaling up in sweetpotato-growing areas in Ethiopia.

Keywords: Agronomic traits; Boiled roots; Mother-baby trial; Root yield; Root dry matter content

Introduction

Sweetpotato [*Ipomoea batatas* (L.)] is a versatile and resilient crop, thriving in a wide range of agro-ecologies. Its ability to produce high yields under suboptimal growing conditions makes it increasingly popular in most sub-Saharan African countries, including Ethiopia (Grunebrg *et al.*, 2009; Yan *et al.*, 2022). In Ethiopia, for instance, it is reported as the crop serving over 20 million people, with its production mainly dominated in the southern, southwestern, southeastern, and western regions of the country (Balcha, 2015; Mekonnen, 2021; Aragaw *et al.,* 2024). The Central Statistical Agency of Ethiopia (CSA, 2022) reported that sweetpotato production covered about 62,115 hectares of land, with a total production of 1,598,838 tons in 2021 only during the *Meher* season, i.e., in one window of production (excluding the *Belg* season). There are two types of sweetpotato varieties currently grown in Ethiopia: white-and orange-fleshed types. Notably, the government of Ethiopia has placed emphasis on the development of orange-fleshed sweet potato, which has been identified as a key crop for scaling up and popularization in drought-prone areas of the country.

In nutrition point of view, OFSP is nutrient-dense crop that contains an abundance of pro-vitamin A, which can help curb malnutrition caused by vitamin A deficiency (WHO, 2011; Gilano *et al.,* 2021). For sustainable implementations, the Ministry of Agriculture (MoA-EDRE, 2024) has recently developed and launched a national sweetpotato and potato research and development strategy. It emphasizes the importance of the sweetpotato crop in the lives of millions of people, as it is a wonderful source of energy, vitamins, minerals, and antioxidants (particularly orange and purple sweetpotatoes and potatoes). In the previous decades, crop breeding and selection criteria were predominantly driven by agronomic gains such as yield maximization and agro-climatic adaptability objectives (Defor *et al.,* 1997), however, the increasing demand for healthy and safe diets, changing sociocultural conditions, and climate-induced challenges have all necessitated a shift in the existing approach, a redesign, and implementation of a new approach based on emerging perspectives (Dwivedi *et al.,* 2017; Campos *et al.,* 2020; Mulwa *et al.,* 2023).

End-user acceptability perception is crucial in variety development for wider adoption of newly released varieties to provide healthy diets, curb hidden hunger, and meet the dynamic preferences of a diverse spectrum of end-users (Mulwa *et al.,* 2023). Among various possibilities, farmers integration as a participatory variety selection approach is the most cost-effective and efficient technique for incorporating consumer perspectives in a systematic way. Based on this approach, in recent years in Ethiopia, participatory variety selection of sweetpotatoes has helped to release three high-dry matter and beta-carotene-rich OFSPs that are currently widely grown in Ethiopia (Gurmu, 2019; Mekonnen, 2021; Aragaw *et al.,* 2024). Jenkins *et al.* (2018) reported that most technologies have been produced and rereleased over the last ten years using a conventional breeding strategy that primarily focuses on agronomic traits, which has led to a slow uptake of improved varieties.

As previously indicated, farmers' integrated variety evaluation plays an important role since it enables for the timely introduction and extraction of farmer perspectives on new technologies. This strategy, also known as participatory variety selection (PVS), is projected to be a faster and cheaper method for identifying new aspects of interest and farmers' preferred varieties (Ceccarelli *et al.*, 2009; Tefera *et al.,* 2013; Mekonnen, 2021).

Since the start of sweetpotato research and development in Ethiopia, about 31 sweetpotato varieties (white-fleshed and orange-fleshed types) have been officially released for cultivation. Half of these were orange-fleshed varieties, which were primarily developed and released by breeders with a focus solely on agronomic traits; however, their adoption rate has remained very low because farmers were not regularly involved in the variety evaluation and selection process to incorporate what consumers demanded from those varieties (Gurmu, 2019).

Based on previous approaches learned through farmers' participation in varietal assessment, a PVS technique proved to be an efficient and simple way to involve farmers in the variety evaluation and selection process prior to release.

For instance, in 2018, over 1000 farmers were participated in a PVS to evaluate and select their best OFSP variety at the final breeding stage before release. With this approach, three farmers' preferred OFSPs were released for production in 2019, and they are now cultivating and performing well in major sweetpotato-growing regions of Ethiopia (Mekonnen, 2021; Aragaw *et al.,* 2024). Therefore, the present study was designed with the objective of farmers' integrated evaluation of elite sweetpotato genotypes and to recommend their preferred varieties for production in the local context of Ethiopia.

Materials and Methods

Study locations, experimental materials, field design and management

The field trial was established at Hawassa, Wondogenet, Halaba, Arbaminch and Fogera representing Sidama region, Central, South, and Amhara regions of Ethiopia under rain-fed condition in 2022 (Table 1). The experiment was conducted in a mother-baby design fashion (Suwarno *et al.,* 2002; Atlin *et at.,* 2002). Six orange-fleshed sweetpotato genotypes (four elite clones and two released varieties that are currently being grown in different parts of the country) were used in the experiment (Table 2). Farmers' training centers (FTCs) at each location was used to establish a mother trial (grand trial) and for a baby trial, planting materials of one new genotype (elite genotype) and two released varieties, for each 200 vine-cuttings as a positive checks were given to thirty farmers around FTC in each location totaling 150 farmers across five locations. The purpose of the baby trial was to extract farmers' perceptions (preferences).

The farmers were first well trained on how to establish baby trial under their cultural/local management.

The consensus with all the participant farmers was that they agreed to come to FTCs, where the mother (grand trial) was established to evaluate, compare, and choose their preferred genotypes. At the harvesting stage, their evaluation points were based on the genotypes they took, planted in their own farm, and managed based on their indigenous knowledge to evaluate and compare each genotype to the rest of the genotypes in a mother trial planted at FTCs. The mother-grand trial was laid out in a randomized completed block design (RCBD) replicated three times. A total experimental plot was 252 m^2 with 12 m width and 21 m length. A single plot for a single genotype was 9 m^2, which consisted of five rows of 3 m length that accommodated 10 plants per row and 50 plants per plot. The spacing between replications was 1.5 m, and between plants and rows was 0.3 and 0.6 meters, respectively. To maintain plant population density per plot per genotype, the dead vine cuttings were replanted with fresh ones after 15 days of the first trial. The rest of the routine cultural practices, such as weeding and earthening up, were done after the fourth week of planting, and all plots were kept weed-free by manually weeding. No fertilizers were applied to this experiment. All plots received recommended cultural practices uniformly following the sweetpotato production manual developed by Hawassa ARC (2015).

Table 1. Description of the experimental sites

Location	Code	Altitude (masl)*	Coordinates	Soil textural class	Annual R.F (mm)	Mean Temperature (°C)		RH (%)
						Min	Max	
Hawassa	HAW	1700	07°03’54”N, 38°28’59”E	Sandy clay loam	1046.3	13.3	27.6	62.1
Halaba	HAL	1772	07°18’38”N, 38°05’38”E	Sandy clay loam	928.8	14.6	28.6	58.3
Wondogenet	WGT	1788	7° 05’E, 38°38’E	Sandy clay loam	1000	12.02	26.72	-
ArbaMinch	AMC	1220	6°6’55”N, 37o35’51”E	Sandy loam	634.4	14.6	32.7	63.2
Fogera	FOG	1560	11°53’30”N, 37°25’45”E	Sandy loam	1000	13.0	30	-

Where, °C = degree Celsius; *=meters above sea level; RH=relative humidity

Table 2. Description of OFSP genotypes used in PVS evaluation in 2022.

S.№.	Name of genotypes	Root flesh color intensity	RDMC (%)	Source of genotypes
1	MUSG014052-51-24	IO	27.0	CIP-Uganda
2	CORDNER-15-11	IO	28.0	CIP-Uganda
3	13NC9350A-9-3	DO	30.0	CIP-Uganda
4	105413-5	IO	30.0	CIP-Uganda
5	Alamura	DO	31.8	Ethiopia
6	Kabode	IO	30.3	Ethiopia

Where, IO= Intermediate orange, DO=Deep orange, RDMC= Root dry matter content, CIP=International Potato Center

Data collection procedures

Data on agronomic traits such as marketable, unmarketable and total root yield in ton per hectare (t/ha), above ground biomass (t/ha), and sweetpotato virus diseases (SPVD) using 1-9 scoring method, root dry matter content (DMC) in %, were recorded from a mother trial following the data recording procedure for sweetpotato (Gruneberg *et al.*, 2019). Data on farmers' perception was collected at two stages i.e. at harvesting and post-harvest stages. At the first stage the evaluation was conducted based on agronomic traits set by farmers, such as early maturity, tolerance to drought, high root yield, disease resistance, root shape, and above-ground vegetative performance at harvest. The second stage involved evaluation of genotypes based on boiled roots specifically for organoleptic properties such as mealiness (powderiness), taste, colour, hardness, and odour of boiled roots.

Statistical analysis

All agronomic data collected from the mother trial were analyzed using SAS software version 9.3 (SAS Institute Inc. 2003). A Least Significant Difference (LSD) technique was employed to compare genotypes at 5% and 1% probability level following the guideline developed by Gomez and Gomez (1984). Farmers' perception data were analyzed using SPSS software (SPSS Inc. 2009).

Statistical model**:** $X_{ij} = \mu + T_i + B_j + E_{ij}$

Where, X_{ij} = the i^{th} treatment effect in j^{th} block, µ = the overall mean, T_i = i^{th} treatment effect (μ_i-µ), Bj is j^{th} block effect (μ_j-µ) and E_{ij} = the effect of i^{th} treatment in j^{th} block. j=1…r, i=1…t.

Results and Discussion

Analysis of variance for nine agronomic traits of OFSP genotypes

Analysis of Variance (ANOVA) showed significant differences ($p<0.01$) among genotypes for yield and its contributing traits studied (Table 3). The significant differences observed among genotypes for all traits considered are a clear indication for the presence of significant genotypic variations across the tested locations. Differences observed may be related to genotypic differences and variations associated with each geographic location where the genotypes were evaluated, such as rainfall pattern, growing season, altitudes, temperatures, and soil type (Jackson and Harrison, 2013).

Table 3. Analysis of variance for nine traits of six OFSP genotypes tested in PVS across locations in 2022

Source of variation (traits)	Mean square					R-square
	Replication (df=2)	Genotype (df=5)	Location (df=4)	Genotype x Location (df=20)	Residual (df=50)	
MRLD	2.78 ^{ns}	378.64***	434.19***	82.91***	6.08	0.95
UMYLD	5.67 ^{ns}	16.42***	53.19***	6.78***	61.24	0.88
TYLD	7.41 ^{ns}	513.23***	628.77***	109.85***	7.70	0.95
AGBM	16.31 ^{ns}	613.92***	4754.00***	346.60***	56.77	0.91
RL	0.97 ^{ns}	65.46***	161.46***	9.75***	5.88	0.80
RG	0.93 ^{ns}	11.84***	1036.19***	13.68***	2.82	0.97
HI	0.01 ^{ns}	0.07***	0.11***	0.03***	0.06	0.80
DMC	9.07 ^{ns}	34.46***	4484.65***	12.80***	5.30	0.98
SPVD	0.28 ^{ns}	5.32***	34.07***	8.12***	0.31	0.95

Note; *** Significant at 0.01%; DF = degree of freedom, MYLD=Marketable root yield, UMYLD=Unmarketable root yield, TYLD=Total root yield; AGFB=Aboveground fresh biomass yield; RL=Root length; RG=Root girth/diameter; HI=Harvest index; DMC=Root dry matter content; SPVD=Sweetpotato virus disease

Mean performance of the genotypes for root yield and yield-related agronomic traits

Highly significant variations ($p<0.001$) were observed among genotypes evaluated at five locations for all traits considered (Table 4). The highest marketable root yields were obtained from genotypes G3 (13NC9350A-9-3) and G1 (MUSG014052-51-24) with values of 25.78 t ha^{-1} and 23.31 t ha^{-1}, respectively. The lowest root yields of 11.41 t ha^{-1} and 13.78 t ha^{-1} were recorded for G4 (105413-5), G2 (CORDNER-15-11), respectively. The mean unmarketable root yields ranged from 1.01 for G3 (13NC9350A-9-3) to 5.56 t ha^{-1} for G5 (Alamura). Genotypes with the highest number of unmarketable roots are characterized as poor genotypes that produce root waste, making them unsuitable for growing marketing roots (Gurmu *et al.*, 2024).

The highest total root yield was obtained from G3 (13NC9350A-9-3) with 26.83 t ha^{-1}) while the lowest total root yield of t ha^{-1} was obtained from G4 (105413-5) 12.20 (Table 4). The observed variation among genotypes may signifies the existence of variations due to genetic makeup of the study material as well as environmental factors associated with soil type, temperature and altitudinal differences (Mbusa *et al.*, 2018). Similar to this finding, Rukundo *et al.* (2017) and Mekonnen *et al.* (2021) evaluated different sweetpotato varieties for root yield and yield-related traits in diverse agro-ecologies and reported the presence of a considerable range of variations for root yields and their contributing traits among the tested genotypes in their studies. In addition to other desirable traits, root yield can be used as a means to selecting the best adapted genotypes to recommend for production in the targeted agro-ecological areas (Mekonnen and Gurmu, 2023). The evaluated genotype showed a significant differences for above-ground biomass ranging from 20.54 to 37.33 t ha^{-1} for G4 (105413-5) and G5 (Alamura) with a mean of 31.1 t ha^{-1}. Significant differences were observed for harvest index among genotypes, ranging from 29% for G2 (CORDNER-15-11) to 48% for G3, with an overall average of 38% (Table 4).

Mean performance of the genotypes for viral disease reaction and root dry matter content

There were significant differences between genotypes in SPVD reaction (Table 4). G4 (105413-5) obtained the highest score whereas G1 (MUSG014052-51-24) and G3 (13NC9350A-9-3) had the lowest score values of 3.80 and 2.00, in their order. The presence of differences in SPVD reaction signifies differential genotypic performance, with their responsiveness to SPVD across testing locations; thus, the observed differences can help determine whether to promote or discard genotypes at later stages (Abebe *et al.,* 2023). Differences were observed for root dry matter contents (DMC) recorded (Table 5). The check variety G5 (*Alamura*) had the highest DMC of 30.0%, whereas G1 (MUSG014052-51-24) had the lowest DMC of 22.6%. The DMC, which is characterized by the mealiness of OFSP cultivars when roots are cooked, significantly influences the acceptability and adoption of releasing sweetpotato varieties (Mekonnen, 2021; Gurmu *et al.,* 2024). Additionally, Mwanga *et al.* (2017) and Tumwegamire *et al.* (2016) stated that an OFSP dry matter level (DMC) defined as medium in the range of 24%–28% and a high DMC >28% are required. Accordingly, the best genotypes are those that fall in the range above 28%.

Table 4. Combined mean for yield and yield-related traits performance of elite OFSP genotypes evaluated across locations in PVS-2022

Code	Genotype	Agronomic traits					
		MYLD (t ha^{-1})	UMYLD (t ha^{-1})	TYLD (t ha^{-1})	AGFW (t ha^{-1})	HI (%)	SPVD (1-9 Scale)
G1	MUSG014052-51-24	23.31^{ab}	3.09^{ab}	26.41^{ab}	34.73^{a}	43^{ab}	2.00^{c}
G2	CORDNER-15-11	13.78^{c}	1.65^{c}	15.43^{d}	32.63^{a}	29^{d}	2.07^{c}
G3	13NC9350A-9-3	25.78^{a}	1.05^{d}	26.83^{a}	26.27^{b}	48^{a}	2.00^{c}
G4	105413-5	11.41^{d}	1.70^{c}	12.20^{e}	20.54^{c}	33^{d}	3.80^{a}
G5	Alamura	16.63^{c}	5.56^{a}	22.19^{c}	37.33^{a}	35^{cd}	2.60^{b}
G6	Kabode	20.55^{b}	2.46^{b}	23.02^{b}	35.03^{a}	40^{bc}	2.40^{bc}
Mean		18.58	2.58	20.60	31.10	38	2.47
LSD (5%)		3.42	1.60	5.60	8.52	9	1.40
Significance		**	*	**	**	**	*
CV (%)		26.70	28.00	28.40	30.21	28.60	27.30

Where, Means within a column followed by the same letter(s) are not significantly different at 5% probability level; *=significant at 5%, **=significant at 0.01%. MYLD=Marketable root yield, UMYLD=Unmarketable root yield, TYLD=Total root yield, AGFW=Above-ground fresh weight, HI=Harvest index, SPVD=Sweetpotato virus disease

Table 5. Combined mean for root dry matter content (%) performance of six OFSP genotypes tested across locations in PVS-2022

S.No̲.	Genotypes	Locations					
		HAW	HAL	WGT	AMC	FOG	Location mean
1	MUSG014052-51-24	16.0	20.0	23.0	24.0	30.0	22.6
2	CORDNER-15-11	24.0	25.0	28.5	27.0	31.0	27.1
3	13NC9350A-9-3	29.0	30.0	28.5	29.0	29.5	29.2
4	105413-5	21.0	20.0	28.0	30.0	29.0	25.6
5	Alamura	30.0	31.0	27.6	30.0	31.2	30.0
6	Kabode	27.0	28.0	31.0	30.0	31.0	29.0
	Mean	24.0	25.6	27.7	28.3	30.2	27.1
	LSD (5%)	4.0	3.0	1.8	2.33	1.33	2.5
	CV (%)	12.7	11.0	13.8	14.6	17.0	13.8

Where, HAW=Hawassa, HAL=Halaba, WGT=Wondogenet, AMC=ArbaMinch, FOG=Fogera

Farmers’ variety assessment, preferences and selection

Variety assessment was conducted at two stages: the first stage focused on agronomic traits before harvest (pre-harvest) and the second stage focused on boiled roots traits after harvest (post-harvest).

Varietal assessment based on agronomic traits of the genotypes

In the first stage of agronomic traits-based variety assessment 60 farmers (50 males and 10 females) were involved from two locations namely *Hawassa*, and *Halaba* (Table 6). At this assessment stage, invited farmers discussed on important characteristics from their indigenous knowledge and they mentioned that agronomic traits such as drought tolerance, high root yield, disease resistance, root shape, and above-ground vegetative performance as the best traits they valued. Based on their aforementioned traits, they evaluated and identified three genotypes G3 (13NC9350A-9-3), G6 (*Kabode*), and G5 (*Alamura*), respectively, as their first, second, and third choices (Table 6). This study concurs with similar process of selection of released orange-fleshed sweetpotato based participatory variety selection approach (Mekonnen, 2021).

Table 6. Varietal assessment by farmers based on agronomic traits at *Hawassa* and *Halaba* in 2022.

Selection criteria set by farmers	N=60					
	Genotypes					
	G1	G2	G3	G4	G5	G6
Early maturity	3	4	1	5	2	3
Resistance to drought	3	1	2	5	3	2
Root yield	2	2	1	4	2	3
Resistant to disease	5	6	1	4	3	1
Root shape	3	5	1	5	2	2
Above ground biomass	2	5	2	5	2	2
Total	18	23	8	28	14	13
Mean	3.0	3.8	1.3	4.2	2.3	2.1
Over all rank of farmers	4	5	1	6	3	2

Where, N= Number of participating farmers on variety assessment using agronomic traits; Farmers' preference ranking was using subjective scale (1-6); 1= 1st choice 6= 6th choice; G1= MUSG014052-51-24, G2= CORDNER-15-11, G3=13NC9350A-9-3, G4=105413-5, G5= Alamura, G6= Kabode

Varietal assessment based on boiled roots traits of the genotypes

Table 7 presents the selection criteria set by farmers based on boiled root traits at the second stage of evaluation (at harvest) to select their preferred OFSP varieties. Before evaluating each variety, farmers (men and women), discussed and established their selection criteria, to determine which variety is the best and which is more likely to be preferred by the majority of farmers. They stated that the primary influencing characteristics that promote the adoption of OFSP cultivars include mealiness (powderiness), taste, colour, hardness, and odour of cooked roots (Table 7). Then, each variety of boiled or cooked roots was tasted one at a time by the farmers who participated in the evaluation process, and their ratings were recorded for each one. Based on the criteria they mentioned, the participating farmers used their subjective ranking system to identify which of their best varieties they liked and which ones they didn't. Farmers consistently evaluated variety based on characteristics of cooked roots in all sites. The mean overall liking of the scored cooked sweet potato variety was used for statistical computations. As most panelists mentioned the color of boiled roots should be visually attractive. The check variety *Alamura* was preferred as number 1 followed by genotype 13NC9350A-9-3 on boiled root color assessment (Table 7). Regarding variety assessment in terms of 'taste', as they mentioned sweet-taste are the preferred trait, the evaluation of genotypes for this trait was subjective; however, the check variety for this trait was selected as the first choice with and the genotype 13NC9350A-9-3 following as the second choice. The criteria that famers mentioned can provide a great opportunity for sweetpotato breeders to include those traits when developing sweetpotato varieties for wide-scale adoption. This finding is consistent with previous works reported by Shikuku *et al.* (2019) and Kikulwe *et al.* (2011), who discovered that taste was an important consuming attribute with a high influence on adoption of improved sweetpotato cultivars. Also, as stated by Lebot (2017), the sweet taste of raw sweet potatoes is attributable to glucose, fructose, and sucrose, whereas the taste of boiling roots is due to maltose produced by starch hydrolysis while cooking.

In terms of mealiness, this trait was recognized as the best among the others; most panelists referred to it as powderiness. According to mealiness, panelists chose the check variety (*Alamura*), genotype (13NC9350A-9-3), and second check variety (*Kabode*) as their first, second and third preferred genotypes, respectively.

Hardness is a mechanical textural quality that determines the force required to accomplish a specific deformation. Panelists classified it with firmness, stating that varieties with a firm characteristic are preferable, but variety with extremely soft, hard, and extremely hard were not preferred by the majority of panelists. Based on this trait, three genotypes, *Alamura*, *Kabode*, and 13NC9350A-9-3, were selected as their best choices in that order, whereas the others were disliked/ penalized by the panelists. These findings are consistent with previous approaches used by Mekonnen (2021) in a participatory variety selection technique. The author also stated that including local farmers in variety evaluation can help to extract their preferences and increase future intake of the recommended varieties.

Concerning the odour of cooked sweet potato roots, the panelists stated that genotypes with an odorless scent when cooked are preferred. They stated that varieties with slightly strong to extremely strong odour (off odour) are classed as low-quality, resulting in rejection of varieties for this attribute.

According to this trait, panelists identified three genotypes as the best: 13NC9350A-9-3, *Alamura*, and *Kabode*, these have been selected as having a pleasant sweetpotato fragrance based on odour testing results. Based on the overall rating using the five organoleptic traits, the first three genotypes were *Alamura*, 13NC9350A-9-3 and *Kabode* were selected as their preferred genotypes, respectively (Table 7). In orange-fleshed sweetpotato, trait preferences impacts the types of sweetpotato varieties demanded, adopted, and used by end users (Mulwa *et al.*, 2023). The authors also explained that farmers' preferences for root and tuber crops differ significantly from those for cereals and legumes, with root and tuber crops ranking higher in terms of cooking, visual, and sensory characteristics. Furthermore, according to Costell *et al.* (2009), sensory tests have a significant role in assessing consumer satisfaction with food quality, which leads to higher acceptance of new technologies of orange-fleshed sweetpotato. Recently, Aragaw *et al.* (2024) conducted a comprehensive on-farm orange-fleshed sweetpotato participatory variety selection trial including over 500 farmers in southern Ethiopia to analyze farmers' perceptions at the final breeding stage. The results of their trials revealed that three farmers' preferred varieties were released, and the varieties are now doing well in varying agro-ecologies in Ethiopia.

Table 7. Farmers' variety assessment and selection based on organoleptic attributes of boiled/ cooked roots across five locations in a PVS in 2022 (N=150)

Genotype name	Organoleptic (sensorial) attributes					Total scores	Mean	Overall rank of farmers
	Color	Taste	Mealiness (mouth feel)	Hardness	Odor			
MUSG014052-51-24	4	4	5	5	5	23	4.6	7.23
CORDNER-15-11	5	6	4	4	4	23	4.6	7.23
13NC9350A-9-3	2	2	2	3	1	10	2	3.14
105413-5	6	5	6	6	6	29	5.8	9.11
Alamura	1	1	1	1	1	5	1	1.57
Kabode	2	3	2	2	1	10	2	3.14

Where, N is the number of farmers who took part in the variety assessment using agronomic traits. Farmers' preferences were ranked using a subjective scale (1–6); 1 = first choice, 6= is the sixth choice.

Conclusion

Orange-fleshed sweetpotato is a versatile crop that can effectively combats hidden hunger by addressing a wide range of customer preferences. Farmers' integrated evaluation of orange-fleshed sweetpotato is critically important for identifying their traits of interest. Further, to ensure adoption and rapid varietal up-scaling with wider acceptance, these traits should be incorporated into varietal evaluations alongside agronomic and other demand-driven characteristics

In this study, farmers set up their own selection criteria based on agronomic traits as well as taste testing of boiling root attributes (organoleptic). Agronomic traits included drought tolerance, high root yield, disease resistance, root shape, above-ground vegetative performance, and taste-test (organoleptic properties) such as mealiness, taste, colour, hardness, and odour after harvest. Evaluations and selections were simultaneously done on agronomic and organoleptic characteristics, as well as performance of genotypes across test locations. The results of this study revealed that three genotypes namely *Alamura*, 13NC9350A-9-3, and *Kabode*, were preferred by famers as their 1st, 2nd and 3rd choices, respectively.

In general, prior to release, evaluating of orange-fleshed sweetpotato genotypes based on consumer-driven preferences, agronomic performance, and taste tests, are useful for identifying genotypes preferred by farming communities for wider cultivation. This contributes to food security and improved nutritional outcomes, particularly for vulnerable groups such as resource-poor communities. Therefore, the selected genotypes namely *Alamura*, 13NC9350A-9-3, and *Kabode* are recommended to cultivate in study areas and areas with similar agro-ecologies of Ethiopia.

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References

Abebe, S. M., F. G. Balcha, and G. G. Mengesha. 2023. Reaction of introduced orange fleshed sweetpotato (Ipomoea batatas L.) genotypes for virus disease resistance and storage root yield performance under field conditions in Dilla and Hawassa, southern Ethiopia. *Indian Phytopathology* 76: 243–259.

Aragaw, A., B. Biazin, F. Gurmu, R. Anthony, M. Cherinet, J. Low, M. Yeshitela, et al. 2024. Participatory on-farm evaluation of new orange-fleshed sweetpotato varieties in Southern Ethiopia. *Open Agriculture* 9.

Atlin, G., T. Paris, T., and B. Courtios. 2002. Sources of variation in participatory varietal selection trials with rainfed rice: implications for the design of mother-baby trial networks. In: Bellion MR, Reeves J, editors. Quantitative analysis of data from participatory methods in plant breeding. Mexico, D.F: CIMMYT; 36–43.

Balcha, F. G. 2015. Breeding of sweetpotato for improvement of root dry matter and β-carotene contents in Ethiopia. ttps://researchspace.ukzn.ac.za/xmlui/handle/10413/14073

Campos, H. 2020. The Innovation Revolution in Agriculture: A Roadmap to Value Creation.

Ceccarelli, S., E.P. Guimara., and E. Weltzien. 2009. Plant breeding and farmer participation. FAO, Rome, Italy.

Costell, E., A. Tárrega., and S. Bayarri. 2009. Food Acceptance: The Role of Consumer Perception and Attitudes. Chemosensory Perception, 3(1):42–50. https://doi.org/10.1007/s12078-009-9057-1

Central Statistical Agency (CSA). 2022. The Federal Republic of Ethiopia Agricultural sample survey 2021/2022. Report on area and production of major crops (Private Peasant Holdings, Meher Season). Ethiopian Statistical Service, Addis Ababa, Ethiopia

Defoer, T., A. Kamara, and H. De Groote. 1997. Gender and variety selection: Farmers' assessment of local maize varieties in Southern Mali. *African Crop Science Journal* 5.

Dwivedi, S. L., E. T. Lammerts van Bueren, S. Ceccarelli, S. Grando, H.D. Upadhyaya, and R. Ortiz. 2017. Diversifying Food Systems in the Pursuit of Sustainable Food Production and Healthy Diets. Trends in Plant Science, 22(10):842–856. https://doi.org/10.1016/j.tplants.2017.06.011

Gurmu, F., B. Mekonnen, and B. Habete. 2024. Evaluation of orange-fleshed sweetpotato genotypes for root yield and yield-related traits in South and Northern parts of Ethiopia. *Cogent Food & Agriculture* 10.

Gilano, G., S. Hailegebreal, and B. T. Seboka. 2021. Geographical variation and associated factors of vitamin A supplementation among 6–59-month children in Ethiopia. *PLoS ONE* 16: e0261959.

Cox, D. F., K. A. Gomez, and A. A. Gomez. 1985. Statistical Procedures for Agricultural research. *Journal of the American Statistical Association* 80: 486.

Gruneberg, W.J., R. Eyzaguirre, F. Diaz, B. Boeck, J. Espinoza, R.O.M. Mwanga, J. Swanckaert, H. Dapaah, M. Andrade, G. Makunde, S. Tumwegamire, S. Agili, F.P. Ndingo-Chipungu, S. Attaluri, R. Kapinga, T. Nguyen, X. Kaiyung, K. Tjintokohadi, R.T. Ssali, T. Carey, and J.

Low. 2019. Procedures for the evaluation of sweetpotato trials. Manual. Lima (Peru). International Potato Center (CIP) ISBN: 978-92-9060-522-5

Hawassa Agricultural Research Center (HwARC). 2015. Sweetpotato production and field management in Ethiopia, Production Manual. Hawassa Agricultural Research Center.

Heck, S., H. Campos, I. Barker, J. J. Okello, A. Baral, E. Boy, L. Brown, and E. Birol. 2020. Resilient agri-food systems for nutrition amidst COVID-19: evidence and lessons from food-based approaches to overcome micronutrient deficiency and rebuild livelihoods after crises. *Food Security* 12: 823–830.

Jackson, D. M., H.F. and Harrison. 2013. Evaluation of dry-fleshed sweet potato genotypes for resistance to soil insect pests, 2011. Arthropod Management Tests, 38(1) https://doi.org/10.4182/amt.2013.M4

Jenkins, M., C. B. Shanks, R. Brouwer, and B. Houghtaling. 2018. Factors affecting farmers' willingness and ability to adopt and retain vitamin A-rich varieties of orange-fleshed sweet potato in Mozambique. *Food Security* 10: 1501–1519.

Lebot, V. 2017. Rapid quantitative determination of maltose and total sugars in sweet potato (Ipomoea batatas L. [Lam.]) varieties using HPTLC. Journal of Food Science and Technology, 54: 718–726.

Mbusa, H., K. Ngugi, F. Olubayo, B. Kivuva, J. Muthomi, and F. Nzuve. 2018. Agronomic performance of Kenyan orange fleshed sweet potato varieties. *Journal of Plant Studies* 7: 11.

Mekonnen, B., and F. Gurmu. 2023 Evaluating the Adaptability of Released and Introduced Orange Fleshed Sweet Potato Varieties in Selected Highland Areas of Southern Ethiopia. Adv Crop Sci Tech 11: 565.

Mekonnen, B., A. Gedebo, and F. Gurmu. 2021. Genetic variability for Yield and Yield Related Traits in Orange-fleshed Sweetpotato Genotypes Evaluated at Hawassa, Ethiopia. *Agriculture Forestry and Fisheries* 10: 28.

Mekonnen, B. 2021. Participatory variety selection of improved orange-fleshed sweet potato varieties at Gedeb district of Gedeo zone, Southern Ethiopia. Journal of Agricultural Science and Practice 6(4):130–135. https://doi.org/10.31248/jasp2020.281

Ministry of Agriculture of Federal Democratic Republic of Ethiopia (MoA-FDRE). 2024. The National Potato and Sweetpotato Development Strategy: 2024-2030, Addis Ababa, Ethiopia, Ministry of Agriculture of the FDR Ethiopia.

Mulwa, C. K., H. Campos, I. Bayiyana, S. Rajendran, R. Ssali, M. McEwan, and S. Heck. 2023. Gendered sweetpotato trait preferences and implications for improved variety acceptance in Uganda. *Crop Science* 64: 1206–1218.

Gurmu, F. 2019. Sweetpotato Research and Development in Ethiopia: A Comprehensive Review. Journal of Agricultural and Crop Science 7(7): 106–118. https://doi.org/10.33495/jacr_v7i7.19.127

Mwanga, R.O.M., Andrade, M.I., Carey, E.E., Low, J.W., Yencho, G.C. and Gruneberg, W.J. 2017. Sweetpotato (Ipomoea batatas L.). In: Genetic Improvement of Tropical Crops (edited by H. Campos and P.D.S. Caligari). Pp. 181–218. Gewerbestrasse, Cham, Switzerland: Springer International Publishing AG.

Rukundo, P., H. Shimelis, M. Laing, and D. Gahakwa. 2017. Combining ability, maternal effects, and heritability of drought tolerance, yield and yield components in sweetpotato. *Frontiers in Plant Science* 7.

SAS Institute Inc. 2003. Version 9.1. SAS Institute Inc., Cary, NC.

Kikulwe, E. M., J. Wesseler, and J. Falck-Zepeda. 2011. Attitudes, perceptions, and trust. Insights from a consumer survey regarding genetically modified banana in Uganda. *Appetite* 57: 401–413.

Shikuku, K. M., J. J. Okello, K. Sindi, J. W. Low, and M. Mcewan. 2017. Effect of Farmers' Multidimensional Beliefs on Adoption of Biofortified Crops: Evidence from Sweetpotato Farmers in Tanzania. *The Journal of Development Studies* 55: 227–242.

SPSS Inc. 2009. SPSS Statistics 18.0, SPSS Inc., Chicago, IL.

Suwarno, B., W.S. Kustiant, and G.N. Atlin. 2002. Participatory selection on upland rice in Sumatra. Proceedings of a DFID-Plant Science Research Programme (PSP), Centre for Arid Zone Studies (CAZS)/IRRI conference, 12-15 march; 2002, IRRI, Los Bangos, Laguna, Philippines. 61-63.

Tefera, T. T., S.N. Al-Niemi, S.I. Rekani, and A. Gunes A. 2013. Participatory variety selection of potato (Solanium tuberosum. L) in southern Ethiopia. Journal of Agri-Food and Applied Sciences1(1):1-4.

Tumwegamire, S., P. R. Rubaihayo, W. J. Grüneberg, D. R. LaBonte, R. O. M. Mwanga, and R. Kapinga. 2016. Genotype × Environment Interactions for East African Orange-Fleshed Sweetpotato Clones Evaluated across Varying Ecogeographic Conditions in Uganda. *Crop Science* 56: 1628–1644.

World Health Organization (WHO). 2011. World Health Statistics. World Health Organization, Geneva.

Yan, M., H. Nie, Y. Wang, X. Wang, R. Jarret, J. Zhao, H. Wang, J. and Yang. 2022. Exploring and exploiting genetics and genomics for sweetpotato improvement: Status and perspectives. Plant Communications 3(5): 100332.