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Registration of an Early-Maturing Orange-Fleshed Sweetpotato Variety Named "*Shafeta*" for Production in Ethiopia

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Abstract

Shafeta (13NC9350A-9-3) is an orange-fleshed Sweetpotato variety that was identified from a multi-location trial comprised of a total of 10 genotypes (9 selected and one standard check, Alamura, which is dominantly growing) evaluated across four different locations (Hawassa, Halaba, Koka, and Arba-Minch), in 2021 and 2022 under rain-fed conditions, with the objective to select best variety for high root yield and earliness. In all test environments, Shafeta outperformed the check (Alamura), with a yield advantage of 41.40%. Then, it was promoted to and conducted in a variety verification trial (VVT) along with two standard checks (Alamura and Kabode) at three locations (Hawassa, Halaba and Arbaminch) on one on-station and two on-farms for one more year in 2023. The results of VVT showed that Shafeta outperformed Alamura and Kabode, with yield advantages of 16.20 and 20.80 percentages, respectively. It consistently performed well and gave higher yields in all test environments. Its additional attributes are earliness, an appealing root shape and flowering profusely (for future crossbreeding). Accordingly, the National Variety Release Committee evaluated the performance of the proposed variety based on afro-mentioned traits and allowed its official release. Therefore, Shafeta variety is recommended for cultivation in mid-to-lowland sweetpotato-growing domains in Ethiopia.

Keywords: Food security; Nutrition; OFSP, Release, VVT

Introduction

Sweetpotato [*Ipomoea batatas* (L.)] is one of the most valuable root crops cultivated for various purposes in warm temperate, tropical, and sub-tropical regions of the world (FAO, 2021; Abebe *et al*., 2023). Its production in the tropics ranks fifth and seventh in world production after rice, wheat, maize, potato, barley, and cassava, with more than 119 million metric tons of yield in annual production, according to reports by FAOSTAT (2022). In Africa (excluding northern Africa) in 2021, 4.21 million hectares of land were covered with sweetpotato production, which yielded 29.11 million tons, according to the report by FAOSTAT (2022). Sweetpotato is considered an essential subsistence crop, particularly in East Africa, where it comes in fourth place (FAO, 2021). In Ethiopia, sweetpotato production covered 62,115 hectares during the 2021 Meher season, with a production of 1,598,838 tons (CSA, 2022).

The production of sweetpotato has remained mainly in the southern, southwestern, and eastern parts of Ethiopia (Gurmu and Mekonen, 2019), but it is being expanded to the northern parts of the country as the government of Ethiopia has recently given due attention to the potential of sweetpotato as a strategic crop for food security in an era of climate change (Gurmu *et al.*, 2017; Gobena *et al.*, 2022). According to the various reports (WHO, 2009; Makunde *et al.* ,2017; Ssali *et al.*, 2019; Laurie *et al.*, 2022; Jaing *et al.*, 2024) challenges currently we are facing such as recurrent drought due to climate-induced threats, vitamin A deficiency (VAD), a rapidly growing human population, the susceptibility of exiting sweetpotato varieties to sweetpotato virus disease, and expansions of urbanization, their ultimate causes call to action to develop climate resilient, nutrient dense, high yielding, and early maturing OFSP varieties that are bio-fortified with beta-carotene (BCC), i.e., an importance source of pro-vitamin A for sustainable production and consumption.

Developing, evaluating, and recommending OFSP varieties enriched with BCC along with other desirable traits such as earliness, high root yield, a good level of dry matter content, and tolerance to sweetpotato virus disease is thus crucial for achieving the contribution of OFSP varieties to meet the intended demands. Low *et al.* (2009) reported that just 125 grams of cooked OFSP root can meet a young child's daily vitamin A requirements. In general, an area of 500 m^2 planted with OFSP variety can provide enough Vitamin A to meet the annual needs of a family of five (Low *et al.*, 2017). Thus, it is critical to address all of the aforementioned issues in a systematic approach by generating best variety for sustainable production. Therefore, to contribute to the efforts of ensuring food and nutrient demands of consumers, the *Shafeta* variety was officially released and registered in 2023 as a new OFSP variety based on its outstanding performance.

Materials and Methods

Descriptions of experimental materials and management

Planting materials were initially introduced from Uganda in the form of botanical seeds that resulted from polycross hybridization. Prior to the establishment of the field trial, over 420 botanical seeds were characterized based on various traits (root yield and yield-related traits, SPVD reaction) following descriptors for sweetpotato (IBPGR, 1991). When the disease signs appeared at each evaluation step, genotypes exhibiting disease symptoms were discarded from each family. Finally, genotypes that demonstrated better performances for the traits of interest were advanced to a multi-environment trial to assess their performance across locations. Accordingly, 10 genotypes (nine selected genotypes along with one standard check) were tested in the national variety trial at three locations (*Hawassa*, *Arbaminch*, and *Koka*) over the course of two years (2021-2022). In 2023, genotype G3 (13NC9350A-9-3) later named *Shafeta* was promoted to test

along with two standard checks that are grown in sweetpotato-growing areas in VVT.

Study locations, field design and trial management

The variety verification trial (VVT) was conducted on one main research station (on-station) and at two farmers' sites (onfarms), 5 km apart from one another onfarm across each location, namely *Hawassa*, *Halaba*, and *Arbaminch* in Central, Sidama, and Southern regions, respectively, under rain-fed conditions in 2023. The field experiment consisted of *Shafeta* variety (13NC9350A-9-3) and two released varieties, namely *Alamura* and *Kabode* that are currently grown across the country and were included as standard checks for comparison. A randomized block design was used, with farmer sites served as replications. A plot size of 10 m in width and 10 m in length with a total area of 100 m^2 that accommodated 555 vine cuttings per plot for each variety was used in the field experimental establishment. The spacing between rows and plants was 0.6 m and 0.3 m, respectively. Replanting was done after two weeks of planting to replace dead vines to maintain the uniformity of the plant population per plot. Cultural operations such as weeding, irrigation (a shower of irrigation during the plant establishment phase, i.e., within two months after planting), hoeing, and earthening-up were done following the technical manual for production of sweetpotato in Ethiopia (Hawassa ARC, 2015).

Table 1 . List of orange-fleshed sweetpotato genotypes used in the multi-location trials during 2021-2022

S/No	Code	Genotype name	Source of genotypes	Status	Root flesh color
1	G1	MUSG014052-51-5	CIP-Udanda	Advanced line	Orange
2	G2	MUSG014001-3-7	CIP-Udanda	Advanced line	Orange
3	G3	13NC9350A-9-3	CIP-Udanda	Advanced line	Orange
4	G4	CN1448-49-26-12	CIP-Udanda	Advanced line	Orange
5	G5	CN1448-49-28-9	CIP-Udanda	Advanced line	Orange
6	G6	107031-18-5	CIP-Udanda	Advanced line	Orange
7	G7	105413-5	CIP-Udanda	Advanced line	Orange
8	G8	105413-13	CIP-Udanda	Advanced line	Orange
9	G9	CORDNER-15-2	CIP-Udanda	Advanced line	Orange
10	G10	Alamura (Check)	Ethiopia	Released in 2019	Orange

Data collection

Data were recorded on sweetpotato virus disease incidence using a 1-9 scoring method, root yield (t ha^{-1}), number of roots per plant (count), root girth (cm), root length (cm), above-ground biomass (t ha^{-1}), root dry matter content (%), and beta-carotene content (mg100 g^{-1}) based on the standard protocol developed for sweetpotato to record each trait (Gruneberg *et al.,* 2019).

Data analysis

Data collected were subjected to analysis of variance (ANOVA) using SAS software version 9.3 (SAS Institute Inc. 2003). Mean comparison was employed using the least significant differences (LSD) technique, following the procedures suggested by Gomez and Gomez (1984).

The following statistical model was used for the analysis of variance for the data that resulted from the VVT trial.

$$X_{ij} = \mu + T_i + B_j + E_{ij}$$

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

Agro-morphological characteristics of Shafeta and its implications for future use

Assessing the agro-morphological characteristics of a crop variety is an important step towards understanding and documenting the range of traits that are essential for its classification and potential cultivation benefits. It was assessed following the standard descriptors developed for sweetpotato by IBPGR (1991) for traits such as vine pigmentation, leaf shape, growth habit, flowering habit, predominant root skin and flesh colour, and root formation, in order to determine the distinctiveness of *Shafeta*. This approach significantly contributes to describe the variety when demanded.

Desirable agronomic characteristics of a newly released Shafeta variety

The variety *Shafeta* has the following positive features that make it preferable as compared to the currently grown OFSP varieties that were used as checks: Early maturity (ready to harvest in three months), higher root yield, 95% of plants in test environments had a profuse flowering habit that can make it used as a parent for future crossing/hybridization works, a root shape appeals to the market, adapts to low-moisture-stress areas, moderately tolerant to sweet potato virus diseases, has a suitable level of dry matter content; comparable beta-carotene (pro-vitamin A) content with the best-check variety (Table 2).

Table 2. Agronomic and morphological characteristics of *Shafeta* (3NC9350A-9-3)

Adaptation areas	Mid-low land areas of Sidama, Southern, Oromia and other regions with similar agro-ecologies
Altitude (m.a.s.l)	1000-1800
Soil texture	Loam and sandy loam
Seed rate (cuttings/ha)	55,555
Spacing (cm)	
Between rows	60
Between plants	30
Planting date	Rain-fed production: from mid June to Mid August Irrigation: can be planted at any time (if frost free)
Fertilizer (kg/ha)	None
Days to maturity	96-110
Petiole length (cm)	15-24
Petiole pigmentation	Most petioles green, some purple
Growth habit	Non-twining and semi-erect
Leaf color at maturity	Green with purple edge
Shape of central leaf-lode	Eliptic
General outline of the leaf	Lobed
Leaf lobe number	5 to 6
Flowering habit	Flowering Profusely enough, mostly flowering under test environments
Axial leaf pigmentation	Mostly green
Predominant root skin color	Red
Predominant root flesh color	Deep orange
Root shape	Round eliptic
Root diameter (cm)	6 to 7.5
Root length (cm)	14 to 16
Individual root weight (kg)	0.4 to 1.1
Root dry matter content (%)	30
Beta-carotene content (Rich in pro vitamin A)	7.4 $mg100g^{-1}$
Texture of cooked roots	Dry and powdery mouth feeling
Color of cooked roots	Deep orange, appealing to all ages
Taste	Sweet
Overall appearance	Excellent
Crop reaction to sweetpotato virus diseases	Moderately resistant/tolerant
Crop reaction to sweetpotato weevil	Moderately tolerant
Root yield (qt/ha,) Research field	300-360
Year of release	2024
Breeder/maintainer	Hawassa Agricultural Research Center

Root yield performance of Shafeta evaluated under variety verification in 2023

The analysis variance revealed the presence of a significant difference ($p<0.001$) in root yield between the three test environments and among the three varieties evaluated. The *Shafeta* (13NC9350A-9-3) variety had a mean root yield of 36.2 t/ha, outperformed the *Alamura* and *Kabode* varieties (standard checks), which yielded 16.2 and 20.8 t/ha, respectively, (Table 3). The *Shafeta* variety performed consistently across test locations and produced higher yields in all locations,

indicating that it is a suitable variety for production in wider areas with moisture shortages.

Table 3. Total root yield (t/ha) performance of Shafeta vs checks Alamura and Kabode tested across three locations (one onstation and two onfarms in each location) in VVT in 2023

Variety	Locations									Mean	
	Hawassa			Halaba			Arba Minch				
	On station	Farmer1	Farmer2	On station	Farmer 1	Farmer 2	On station	Farm er1	Farmer2	Onstation	Onfarm
Shafeta	30.6	29.6	24.7	30.4	28.5	24.6	47.2	34.3	22.2	**36.2**	**27.3**
Alamura	22.7	22.0	17.3	18.6	16.0	17.3	7.4	9.3	12.0	**16.2**	**15.7**
Kabode	18.2	21.1	15.4	16.5	13.5	15.5	27.7	32.4	11.1	**20.8**	**18.1**
Mean	23.8	24.2	19.1	21.8	19.3	19.1	27.4	25.3	15.1		

Performance of the genotypes for resistance to SPVD, number of roots per plant, root girth and root length, root dry matter content, beta–carotene content, days to maturity and flowering ability

Table 4 presents the mean sweetpotato virus disease (SPVD) reaction scores, days to maturity, dry matter content, and flesh color of the varieties. The mean SPVD score of the varieties in VVT ranged from 1.16 (no visible symptom) for varieties *Shafeta* (13NC9350A-9-3) and *Kabode* to 2.60 (some leaves showed virus-like symptoms) for *Alamura* variety. This shows that *Shafeta* showed a high level of tolerance/resistance to SPVD reaction under test environment (Abebe et al., 2023). The root girth trait varied from 5 cm for Kabode to 6.38 cm for *Shafeta*. In addition, a maximum root length of 14.60 cm was recorded for *Shafeta* whereas a minimum of 14.24 cm was observed for Kabode (Table 4). When selecting sweetpotato genotypes, it is important to consider root traits like length and girth. Suitable genotypes include those with early bulking and roots of appropriate size, i.e., root length no longer than 15 cm, smallest no less than 10 cm, and root-girth/ diameter at least greater than 4 cm; this is practically what most consumers stated as their ideal root sizes, and it is now incorporated in the target product traits profile (Targeted traits profile document, unpublished).

The root dry matter content (DMC) of the variety is the main factor influencing the adoption of OFSP varieties, especially among consumers in East African countries, including Ethiopia. In order to meet consumer preferences in the humid tropics, Mwanga et al. (2016) and Tumwegamire et al. (2016) state that an OFSP dry matter level defined as medium in the range of 24% -28% and a high dry matter content >28% are required.

In this study, DMC trait ranged from 28.2% for the *Kabode* to 31.0% for the *Alamura* variety, and *Shafeta* variety has 30.0%. A DMC content of more than 25% is acceptable in orange-fleshed sweetpotatoes. Although all three varieties

evaluated in VVT showed a significant level of DMC, *Shafeta* variety had a dry matter content that was extremely similar to the positive check variety *Alamura*. It is a desirable level because Ethiopian farmers prioritize OFSP varieties with high DMC in their selection process (Gurmu *et al.*, 2017; Gurmu and Mekonen, 2019).

Another key trait of the OFSP variety is its beta-carotene (BCC) content, which functions as a precursor to vitamin A and is well-known for its potential to effectively intervene in areas where vitamin A deficiency is prevalent (Burgos *et al.*, 2009; Low *et al.*, 2017; Gurmu, 2019). In this study, Shafeta had comparable levels of BCC with one of the positive checks Alamura, with values of 7.46 and 7.76 mg/100 g, respectively, which is in line with the range of most favorable genotypes, which may be defined as orange/intermediate orange ranging from 5.08 to 8.36 mg/100 g on a fresh weight basis using the standard procedure developed by Burgos *et al.* (2009). Genotype evaluation for days to maturity is important in areas with irregular/erratic rainfall to ensure food availability in a short period of time, as well as to allocate that land for future crop planting. In this situation, genotypes that mature quickly, within 3 to 4 months, are preferred (Gurmu, 2019). The *Shafeta* variety (13NC9350A-9-3) had the shortest days to maturity (96-105 days), while *Alamura* had the longest (120-150 days). Early maturing genotypes are vital in today's ever-changing climate to provide food and nutritional security, particularly for smallholder farmers, while also providing options for intercropping and relay cropping to boost production and productivity.

Table 4. Combined mean performance of varieties for SPVD reaction, root yield-related traits, DMC and BCC evaluated in VVT in 2023.

Variety	SPVD (1-9)	NRPP (count)	RG (cm)	RL (cm)	DMC (%)	BCC (mg /100g)	DTM (days)	Flowering habit
Shafeta	1.16	5.17	6.38	14.60	30.00	7.46	96-105	Flowering Profusely enough
Alamura	2.60	4.17	5.54	14.40	31.00	7.76	120-150	Mostly not flowering
Kabode	1.33	2.8	5.00	14.24	28.20	5.46	120-126	Mostly not flowering
Mean	1.70	4.04	5.64	14.41	29.73	6.61	112-127	

Where, SPVD = Sweetpotato virus disease (1-9 scale, 1 = immune, 9 =Susceptible, hence 1-3 = resistant, 4 – 6 = medium and 7-9 = susceptible); NRPP=Number of roots per plant; RG=Root girth; RL=Root length; DMC=Dry matter content; BCC=Beta-carotene content on fresh weight basis; DTM = Days to maturity

Figure 1. Performance of *Shafeta* at one of the test locations in VVT (2023)

Conclusion

Development of early maturing crop varieties is important to meet human food and nutrition demands within a short production window. More crucially, global climate dynamics require the development of a resilient OFSP variety that can adapt to changing environments and shocks, which could assist efforts to improve food security and nutrition. The present study was designed with an emphasis on the development of orange-fleshed sweetpotatoes for early maturation in order to ensure sustainable production and food security under climate change. Thus, *Shafeta* variety was evaluated in a variety verification trial along with two currently growing OFSP varieties as standard checks (*Alamura* and *Kabode*). The result of the variety verification trial revealed that *Shafeta* variety showed outstanding performance over standard checks in terms of root yield, early maturation, tolerance or resistance to sweetpotato virus diseases, and adaptability to low moisture-stress areas. Additionally, *Shafeta*, with its semi-erect and non-twining growth habits, as well as its early maturity, can provide an opportunity for intercropping and relay-cropping systems. It also has an appealing root shape (the

most market-preferred characteristic), which can also make it suitable for the export market. Therefore, *Shafeta* variety has been released and recommended for cultivation in the mid-to-lowland sweetpotato growing domains in Ethiopia.

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