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Evaluating the Adaptability of Released and Introduced Orange-Fleshed Sweet potato Varieties in Selected Highland Areas of Southern Ethiopia

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Abstract

Sweetpotato is a versatile crop playing an immense potential in the global food system. The objective of this study was to select outperformed sweetpotato varieties to recommend for highland areas in Ethiopia. Nine orange-fleshed sweetpotato varieties (OFSP) were evaluated at two highland areas, Bursa (2348 masl) and Gedeb (2358) districts, Sidama region and Gedeo zone of southern Ethiopia, respectively during the main cropping season over two years. A Randomized Complete Block Design (RCBD) in three replications. Data were recorded on sweetpotato virus disease score, above ground fresh biomass, root length, root diameter, marketable root yield, unmarketable root yield and total root yield and subjected to combined analysis. The results of analysis of variance showed highly significant differences ($p<0.001$) between varieties, locations and their interactions. The three way interaction effects (variety x location x year) were significant at ($p<0.005$) for marketable and total root yields and non-significant for the rest of traits studied. This suggests that there is an opportunity to select better adapted varieties for highland areas. Combined mean value for SPVD scores ranged from 1.58 to 2.67 (1 to 9), these values indicated resistance/tolerance ranges, implying that most of the tested varieties showed tolerance to SPVD in the tested areas. Variety Mayayi followed by Alamura gave the highest above ground biomass of 20.50 and 20.22 t ha^{-1}, respectively, while Kyoyabwerer gave the lowest yield of 8.00 t ha^{-1} as compared to the others. The maximum marketable root yield was recorded from Kulfo (13.15 tha^{-1}) followed by Kabode (10.05 t ha^{-1}) and Alamura (9.50 t ha^{-1}) whereas the minimum value of 5.70 t ha^{-1} was obtained from NASPOT-8. Three varieties, namely Kulfo, Kabode and Alamura gave a total root yield of 13.53, 10.71 and 10.40 t ha^{-1} respectively. Although Kulfo variety better root yield, however, it is characterized with low dry matter content (DMC) so that its acceptance by farmers remained very low. Varieties Alamura and Kabode were improved varieties and they are known for their high DMC. There is an increasing demand for these varieties because of their high DMC and beta carotene content. Introducing these varieties into cereal-based farming systems can reasonably contribute in highland areas where malnutrition is a serious problem due to high dependency on cereal crops. Therefore, varieties Kabode and Alamura should be recommended for production in highland areas that goes up to 2350 m above sea levels.

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Adaptation, highland, location, root yield, sweetpotato, human consumption.

Introduction

Sweetpotato [*Ipomoea batatas* (L) Lam] is a flexible crop of immense potential with its ability to adapt a to wider range of environmental conditions (Niringiye *et al.,* 2014; Andrade *et al.,* 2016; Fekadu *et al.,* 2017). Globally, sweetpotato is cultivated in more than 115 countries (FAOSTAT, 2019). In Ethiopia, it is dominantly grown for human consumption in the Eastern, Southern and Southwestern parts of the country (Fekadu *et al.,* 2015). The crop can be consumed as a healthy diet by about 20 millions of people across the country (Fekadu *et al.*, 2015).

The importance of orange fleshed sweetpotato (OFSP) is becoming one of the strategic crops for the intervention to nutrition sensitive agricultures as a means to combat problems associated with malnutrition. The crop is grown primarily for its storage roots worldwide; however, both storage roots and leaves can be potential sources of human nutrition.

Currently, encouraging efforts are being made on the leaves of some sweetpotato varieties that are found effectively to be consumed as a vegetable in some parts of southern Ethiopia. Besides, research findings elsewhere by various authors (Islam *et al.*, 2002; Johnson and Pace, 2010) indicated that the young sweetpotato leaves are rich in polyphenolics, protein, vitamins and minerals and are used as a green vegetable. In Ethiopia, most of the communities living in highland areas are expected to have small plots of lands as compared to their family sizes and these lands are occupied relatively with some crops such as Enset, Maize and Potato. These areas are densely populated and malnutrition which is associated with lack of food diversification is a critical issue. OFSP is known for high nutritive values with wider adaptability including low input requirements thereby it can be considered as a best means for intervention to contribute to the reduction of malnutrition (Lebot 2009; Ziska *et al.,* 2009; Fekadu *et al.,* 2017). Thus, evaluation of available released and introduced OFSP varieties in highland areas is a key approach to recommend best adapted varieties for production and promotion for human consumption. Therefore, variety evaluation works was conducted using nine released and introduced OFSP varieties at two locations, namely Bursa and Gedeb districts in Sidama region and Gedeo zone of Southern Ethiopia over the two main growing seasons (2020/21 and 2021/22) with the objective of identifying well adapted varieties for highland environments.

Materials and Methods

Description of the study sites

The study was conducted at Gubeta kebele of Gedeb district of Gedeo zone (5°54.056'N; 38°15.384'E; 2350 m.a.s.l) and Bursa kebele of Bursa District of Sidama region. (6°32.883'N; 38°38.374'E; 2348 m.a.s.l). Both of the sites were characterized as highland areas with well drained soil types. The major crops grown in Gedeb areas are Enset, Potato, Wheat, highland maze, barley and other root crops in the near vicinity whereas, Enset, Potato, Barley and highland maze are among some of dominantly grown crops in Bursa district. In both areas farmers have high interests for the production of sweetpotato varieties that are adapted to their environments.

Experimental materials, field design and procedure

Field trials were conducted using nine released and introduced orange-fleshed sweetpotato varieties. The study materials were collected from Hawassa Agricultural Research Center (five released in Ethiopia and four introduced from Uganda, Kenya and Mozambique). The description of the varieties is shown in Table 1.

Experimental design and field management

The experiment was laid out in a Randomized Complete Block Design (RCBD) in three replications. The size of plot for each variety was 2.4m width and 3m long with an area of 7.2 m^2. There were four rows/ridges per each plot that accommodated a total of 40 plants/cuttings. The spacing between plants and rows were 0.3 m and 0.6m, respectively. The spacing between replications was 1.5 meter. One plant (vine cutting) of 30 cm length with 5-8 nodes was planted in each plot in the prepared holes by burying one-third of the plant in the ground. Replanting was done to replace dead vines after one week of planting and Earthing up was done after fourth week of planting and all plots were kept weed free manually by farmers. All plots received the recommended cultural practices uniformly and no fertilizer was applied.

Data collection

Data were collected from the two central rows excluding the two plants grown at both ends of the row and the two border rows. The following yield and yield related parameters were recorded at harvesting:

Sweetpotato Virus Disease (SPVD)

Recorded on plot basis, using a scale of 1 to 9, where 1 = No virus symptoms; 2 = Unclear virus symptoms; 3 = Clear virus symptoms for < 5% of plants per plot; 4 = Clear virus symptoms for 6–15% of plants per plot; 5 = Clear virus symptoms for 16–33% of plants per plot; 6 = Clear virus symptoms for 34–66% of plants per plot (i.e. > 1/3 and <2/3); 7 = Clear virus symptoms for 67–99% of plants per plot (2/3 to almost all); 8 = Clear virus symptoms for all plants per plot (not stunted); and 9 = Severe virus symptoms for all plants per plot (stunted) as per the procedure developed by Gruneberg *et al.*, (2019).

Aboveground fresh weight biomass (t ha-1)

The weight of above ground parts of the two central rows was taken and converted to t/ha.

Root length (cm): is the length of storage root that was measured from distal to the proximal end on five randomly taken plants at harvest.

Root girth (cm): is the diameter from the middle portion of the storage root. The girth of all the storage roots of each of the sampled plants were measured by using caliper and divided by number of storage roots from all plants sampled and expressed in centimeter.

Marketable root yield (t ha^{-1}): is the weight of clean, uninfected storage roots that fall in the size range of 100g-500g. It was taken by weighing all the storage roots collected from the harvestable plot by using beam balance and expressed as t/ha.

Unmarketable root yield (t ha^{-1}): is the weight of infested, under sized (less than 100 g), over sized (more than 500 g) bruised, or cut storage roots. It was taken by weighting all the storage roots collected from the harvestable plot by using beam balance. It was expressed as t/ha.

Total root yield (t ha^{-1}): is the sum total of both marketable and unmarketable storage root yields obtained from the harvestable plot. And then it was expressed as t/ha.

Yield per hectare: this was obtained from harvestable plot (net plot) and converted in to yield per hectare by using the formula written below and was expressed as ton per hectare

$$\text{Yield per hectare in tones} = \frac{\text{Yield per net plot (kg) x 10}}{\text{Net area of the plot (m}^2\text{)}}$$

Data analysis

Analysis of variance

Collected data on root yield and its components were subjected to analysis of variance using SAS package (SAS 9.3). Data were checked for homogeneity of error variance for the two locations over years using F-ma and it was not significant and then, combined analysis was performed. Least significance differences (LSD) technique was employed to compare the treatments following the procedures of Gomez and Gomez (1984).

The following statistical model was used for combined analysis of variance over locations:

$$Yijkl = \mu + Gi + Lj + GLij + Rk(j) + Bl(k) + \varepsilon ijkl$$

Where: Yijkl is observed value of varietye *i* in block *l* and replication *k* of location *j*, μ is grand mean, Giis effect of variety *i*, Ej is location effect, GEij is the interaction effect of genotype *i* with location *j*, Rk(j) is the effect of replication *k* in location *j*, Bl(k) is the effect of block *l* in replication *k*, ϵijkl is error (residual) effect of genotype *i* in block *l* and replication *k* of location *j*.

Results and Discussion

Analysis of variance for root yield and yield related traits

The mean squares of analysis of variance showed the presence of highly significant differences (p<0.001) for root yields and yield related traits between the four environments among nine genotypes (Table 2).

Highly significant differences were observed among the varieties for all traits considered (p<0.001). Significant differences were observed with the variations due to locations for most of the recorded traits except unmarketable root yield, suggesting differential response of varieties across locations. Highly significant differences (p<0.001) were observed among varieties, locations and their interactions almost for most of the traits under study. The three way interaction effects (variety x location x year) were significant at (p<0.005) for marketable and total root yields and non-significant for the rest of traits studied (Table2).

The existence of significant difference between locations (location main effect) is mainly due to environment, edaphic or management factors prevailing at the specific sites. Similar findings reported the presence of significant difference in root yield of genotypes across various environments (Abdissa *et al.*, 2012; Fekadu *et al.*, 2017; 2019). Also, Harrison and Jackson (2011) observed yield variation between sweetpotato varieties and the authors further explained as these variation might be attributed to differences due to varieties, length of growing season, cultural management and environmental conditions. The results also showed highly significant differences for the interactions of varieties by locations which indicated that there is an opportunity to select the best adapted genotypes for production in highland areas (Bililign and Fekadu, 2021).

Mean root yield performance of orange-fleshed varieties at highland areas

The combined mean values of the varieties for marketable root yield ranged from 5.70 to 13.15 tons per hectare with an overall mean of 8.05 t ha^{-1}. Variety designated as V9 (Kulfo) gave better marketable root yield of 13.15 t ha^{-1} while variety V4 (NASPOT-8) produced the lowest marketable root yield of 5.70 t ha^{-1} as compared to the others (Table 3). All the studied varieties showed the lowest unmarketable root yield which was less than 1 ton per hectare. The high and low temperature extremes play a key role in sweetpotato storage root initiation and bulking at its critical phinophase (Gjanayake *et al.*, 2014).

Although the obtained root for most of the tested varieties was found between acceptable ranges, the characteristics of low temperature in highland areas (at high altitude) expected to have an influence on sweetpotato root development and bulking ability. The size of the roots is very important since roots with less than 100 g are considered under sized and those with more than 500 g are labeled as over sized and not preferred by the consumer. The under-sized roots are considered as unmarketable. Varieties with low mean values for unmarketable root yield (t ha^{-1}) can be considered as better varieties with less wastage. The highest total root yield of 13.53 t ha^{-1} and the lowest total root yield of 6.03 t ha^{-1} were recorded for variety V9 and variety V4, respectively. In addition to other traits, root yield can be used as a means for selecting the best adapted variety to recommend for production in the target agro-ecological areas (Budi *et al.*, 2015; Fekadu *et al.*, 2019; Bililign and Fekadu, 2021).

The result of this study suggested that it can be used as an entry point to diversify the production of sweetpotato in high land areas (up to 2400 m.a.s.l). The three varieties such as V9 (Kulfo), V2 (Kabode) and V7 (Alamura) produced total root yield of 13.53, 10.71 and 10.40 t ha-^{1}, in that order, implying that they can be potential varieties for further production in the study areas and other areas with similar agro-ecologies (Table 3). Although the yield obtained seemed not comparable with yields of the low and midlands areas, the study is the first of its kind in evaluating sweetpotato adaptation to high altitude areas and can be considered as a promising result. However, there were some research reports by Vinaj and Babu, (2006) on variability for yield and yield components in sweetpotato can be attributed to genetic and environmental factors. These authors explained that altitude differences reasonably influence genotypes' performance for root yield and yield components.

Reaction of OFSP varieties to SPVD

Highly significant differences existed within the nine varieties, between the two locations and their interactions over years for SPVD reaction (Table 2). However, the two way interaction (VxY) and the three way interaction (VxLxY) effects were non-significant.

Although significant differences were observed between the tested varieties, the obtained result showed resistance/ tolerance of the varieties to SPVD with low scores of < 3.0 (Gruneberg *et al.*, 2019). Various reports indicated that SPVD is the most destructive disease that can cause root yield reduction by over 90% on sweetpotato world, especially in East Africa (Karyeija *et al.*, 2000; Gutierrez *et al.*, 2003). In this study, mean values for SPVD scores of the nine varieties varied from 1.58 to 2.67 corresponding for varieties V6 (Mayayi) and V1 (Birtukane), respectively (Table 3). These low scores for the reaction to SPVD in tested areas might be attributed to low level of virus diseases pressure in the highland conditions (highland areas) Varieties with better root yield performance and low SPVD severity scores can be considered as a selection means to recommend for production in highland areas.

Table.1 List of orange-fleshed sweet potato varieties used for the study

S.No.	Variety name	Source	Year of release	Root flesh colour
1	Birtukane	HwARC	2008	Intermediate orange
2	Kabode	HwARC	2019	Intermediate orange
3	Dilla	HwARC	2019	Deep orange
4	NASPOT-8	CIP-Uganda	2007	Intermediate orange
5	Kyoyabwerer	CIP-Kenya	1995	Deep orange
6	Mayayi	CIP-Kenya	1995	Intermediate orange
7	Alamura	HwARC	2019	Deep orange
8	Amelia	CIP-Mozambique	2011	Deep orange
9	Kulfo	HwARC	2005	Light orange

HwARC=Hawassa Agricultural Research Center

Table.2 Analysis of variance for root yield and yield-related traits of nine orange-fleshed sweet potato varieties evaluated at four environments.

Source of variation	df	Mean squares						
		SPVD	AGFW	RL	RG	MYLD	UMYLD	TYLD
Variety (V)	8	1.80***	264.80***	17.00***	8.23***	37.23***	0.45**	37.80***
Reps (Y*L)	6	0.70**	58.08 ^{ns}	1.90 ^{ns}	0.76 ^{ns}	6.96 ^{ns}	0.19 ^{ns}	6.20 ^{ns}
Location (L)	1	30.08***	291.03**	57.74***	17.87***	18.33 **	0.01 ^{ns}	17.45**
Year (Y)	1	10.08***	327.57***	0.03 ^{ns}	2.54 *	19.12**	0.02 ^{ns}	18.05**
VxL	8	0.82**	312.67 **	8.00***	2.81***	8.31 **	0.25 ^{ns}	18.40 **
VxY	8	0.3^{ns}	30.38 ^{ns}	2.50 ^{ns}	0.67 ^{ns}	29.04***	0.26 ^{ns}	33.85***
LxY	1	4.08***	1134.84***	72.64***	24.72***	125.80***	0.06 ^{ns}	120.31***
VxLxY	8	0.30 ^{ns}	30.38 ^{ns}	2.50 ^{ns}	0.67 ^{ns}	13.40**	0.24 ^{ns}	14.42**
Error	64	0.23	43.04	1.92	0.40	4.67	0.16	4.30

Where: SPVD=Sweet potato virus disease, AGFW=above ground biomass, RG=Root girth, RL=Root length, MYLD=Marketable root yield, UMYLD=Unmarketable root yield, TYLD=Total root yield

Table.3 Mean performance of sweet potato genotypes for root yield and yield related traits evaluated across two locations over two cropping seasons (2020/21 and 2021/22).

Variety code	Variety name	Agronomic characters						
		SPVD (1-9)	AGFW (t ha^{-1})	RL (cm)	RG (cm)	MYLD (t ha^{-1})	UMYLD (t ha^{-1})	TYLD (t ha^{-1})
V1	Birtukane	2.67	19.71	13.47	4.13	6.87	0.75	7.61
V2	Kabode	1.62	14.00	10.43	4.00	10.05	0.66	10.71
V3	Dilla	2.42	19.04	11.63	3.22	7.67	0.42	8.08
V4	NASPOT-8	1.83	19.01	11.66	4.52	5.70	0.34	6.03
V5	Kyoyabwerer	2.33	8.00	10.00	5.22	7.65	0.35	8.01
V6	Mayayi	1.58	20.50	12.05	4.00	7.21	0.50	7.81
V7	Alamura	2.25	20.22	10.15	3.13	9.50	0.85	10.40
V8	Amelia	2.00	17.80	10.33	4.03	6.12	0.23	6.40
V9	Kulfo	1.70	14.67	10.12	5.70	13.15	0.37	13.53
Mean		2.05	15.83	11.08	4.22	8.05	0.50	8.56
LSD (0.05)		0.70	4.21	1.40	0.80	1.21	0.23	1.70
CV (%)		23.68	30.12	17.50	25.00	31.46	29.34	26.73

Where: SPVD=Sweet potato virus disease, AGFW=above ground biomass, RG=Root girth, RL=Root length, MYLD=Marketable root yield, UMYLD=Unmarketable root yield, TYLD=Total root yield.

Performance of varieties for above ground biomass, root length and root girth

Combined analysis of variance showed the existence of a highly significant difference ($p<0.05$) between varieties, locations and most of their interactions (Table 2). The mean performance of the varieties for above ground biomass ranged from 8.0 to 20.5 t ha^{-1} with an overall mean of 15.83 t ha^{-1}.

Two varieties V7 (Alamura) and V6 (Mayai) produced above ground biomass yield of 20.22 and 20.50 t ha^{-1}, respectively. This might suggest that those varieties with good above ground biomass can reasonably be used for dual purpose (for human consumption and feed for livestock). The root length of the tested sweetpotato varieties was significantly varied. The long root length of 13.47 cm was obtained from variety V1 (Birtukane) whereas the shortest length of 10.00 cm was recorded for V5 (Kyoyabwerer). The largest and smallest root girth was recorded for varieties V9 (Kulfo) and V7 (Alamura) with values of 5.70 and 3.13 cm, respectively with an average mean value of 4.22 cm. The variations in the length and diameter of the roots of sweetpotato have been reported by various authors (Rahman *et al.,* 2015; Reddy *et al.,* 2018). The authors explained that such variation in sweetpotato may be attributed to soil types, soil fertility and productivity, cultivation techniques adopted, environmental factors and genetic makeup of the variety.

Adaptation study of improved OFSP varieties in highland environments is a key approach for contributing to food and nutrition security of the communities that are mainly based on cereal farming. Evaluation of nine OFSP varieties for root yield and yield related traits was conducted at two areas that can be characterized as highland environments. Out of the nine tested varieties, two varieties (Kabode and Alamura) showed relatively good performance at the target areas. These varieties can be recommended for production in the study areas and areas that share similar agro-ecologies.

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