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Performance Evaluation of White-Fleshed Sweet Potato (*Ipomoea batatas* (L.) Lam) Varieties at Buno Bedele Zone, Southwestern Ethiopia

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Abstract

Sweet potato is a vital food security and income generation crop in Ethiopia. This study was conducted to evaluate the performance and adaptability of six white-fleshed sweet potato varieties (Hawasa- 09, Barkume, Tola, Adu, Hawasa-83, and a Local check) across three districts (Gechi, Bedele, Dabo) in the Buno Bedele Zone in 2023 to 2024 cropping seasons. A randomized complete block design (RCBD) with three replications was used. Collected data including days to maturity, root length, root diameter, number of roots per hill, Marketable root yield, Unmarketable root yield, Average root weight, and total root yield. The combined data were analyzed using SAS and Genstat 18 statistical software. Analysis of variance revealed highly significant ($p<0.01$) differences among varieties, locations, and years for most traits. The Additive Main Effects and Multiplicative Interaction (AMMI) analysis further quantified a significant genotype-by-environment interaction, with the environment explaining 63.16% of the total variation. Hawasa-09 and Tola were identified as high-yielding and stable varieties across test environments, with mean total root yield of 54.71 and 47.18 t ha^{-1}, respectively. In contrast, Hawasa-83 (39.57) and the Local (39.73 t ha^{-1}) varieties showed consistently lower yields. The study concludes that Hawasa-09 and Tola were well-adapted to the agro-ecologies of Buno Bedele Zone and are recommended for demonstration and dissemination to enhance productivity and food security.

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Root Yield, White Fleshed Sweet potato, Food security

Introduction

Sweet potato is one of the most important food security crops in the world, with an approximate production of 106 million tons from 8 million hectares of land (FAO, 2021; Mekonnen *et al.,* 2015; Emmanuel *et al.,* 2021). Sweet potato is a paramount food security crop, ranking as the seventh most significant food crop globally and serving as a crucial source of energy, vitamins, and minerals for millions in developing countries (FAO, 2021). In Africa, sweet potato is the 2nd most important root crop after cassava (CIP, 2020; FAO, 2021). In many developing countries, sweet potato is reported to be the fifth most important food crop after rice, wheat, maize, and cassava (Abdissa *et al.,* 2012; Amare *et al.,* 2014; Afuape, 2014). Ethiopia is one of the largest sweet potato-producing countries in the world in terms of food security and economic crops (Amare *et al.,* 2014; Emmanuel *et al.,* 2021). Awel (2018); Tadele *et al.,* (2022) reported Ethiopia is increasingly recognized as a strategic crop for combating food insecurity and malnutrition, particularly due to its adaptability to diverse agro-ecologies, short growing cycle, and high yield potential on marginal lands where other cereals may fail. Yet again, Chemeda *et al.,* (2016) and Gurmu (2019) reported that nearly 20 million Ethiopians are dependent on sweet potato as a staple food, reflecting the importance of the crop for food security and the livelihoods of rural communities.

Currently, sweet potato is being distributed to drought-affected areas of the country where maize and other crops regularly fail due to recurrent droughts for food, feed, and economic uses (Madawal *et al.,* 2015; Gurmu, 2019; Getachew *et al.,* 2020; Maimouna *et al.,* 2023). Despite its potential, the average yield of sweet potato in Ethiopia remains low compared to research yields and global averages. According to the CSA (2022), sweet potato occupied about 39,939.10 hectares of land with a total annual production of 17.56 million tons during the main growing season only.

The average national productivity is (33.51 t ha^{-1}), which is below the potential yield on the research station, which is 30 -73 t ha^{-1} (Mulualeam *et al.,* 2022; Mekonnin *et al.,* 2022). The yield gap is primarily attributed to the widespread use of low-yielding, unimproved local cultivars, which are often susceptible to pests, diseases, and have poor market qualities (Tesfaye *et al.,* 2019, and Mwanga *et al.,* 2021). Among the problems, shortage of improved varieties adaptable for different agro-ecologies and resistant to insect pests is some of the factors that hinder crop production**.**

The Buno Bedele zone has a great potential to produce sweet potato. During the 2022 cropping season, sweet potato was cultivated on about 405.53 hectares of land (CSA, 2022). However, the average yield was very low compared to the potential of the crop. The lower yield may be due to abiotic, biotic and socioeconomic constraints before and after harvest among those (Bikamo and Ebrhim, 2023). Among those, lack of improved varieties, are the major hindrance to embarking on higher production in the area. Thus, evaluation of high-yielding, well-adapted, and farmer-preferred varieties are therefore critical components of any strategy to improve productivity and farmer livelihood. Therefore, the objective of the study was to identify adaptable, high-yielding and diseases tolerant sweet potato variety/ies for the study areas and similar agro ecologies.

Materials and Methods

Description of Study Sites

The field experiment was conducted in three testing locations namely Bedele, Dabo Hana, and Gechi which are considered as the representative sweet potato growing areas of southwestern Ethiopia (Abdeta *et al.,* 2023). The experiment was conducted for two cropping seasons (2023-2024) in all three locations. This made a total of six environments, considering one location and one cropping season as one environment.

Plant Materials, Experimental Design and Management:

A total of six white-fleshed sweet potato varieties, including local check were used for this study. The varieties were selected based on their high yielding potential. The experiment was laid out as a Randomized complete Block Design (RCBD) with three replications in each environment. Each sweet potato varieties were assigned to one plot in each replication. The gross plot size for each treatment was 2.4 x 2.4=5.76m^2, using inter-row spacing of 60cm and intra-row spacing of 30cm.

Vines of the same size and age were used as planting material. One month after planting, seedlings were earthed up, followed by frequent weeding. All other agronomic practices were followed according to the recommendations.

Data Collection and Analysis

Data were collected from ten pre tagged plants from each plot, and the average values were used for data analysis. The trait that are used for data collection were: Days to maturity, marketable storage root number, storage root length (cm), storage root diameters (cm), and total storage root weight (t ha^{-1}). Homogeneity of residual variance was tested before combined analysis over locations in each year, as well as over locations and years. Accordingly, the data collected indicated homogenous variance. A normality test was also conducted, and all data showed normal distribution.

A combined analysis of variance was performed using GenStat 18th Edition and SAS version 9.2.Analytical Procedures: Combined Analysis of Variance (ANOVA), AMMI analysis, and bi-plot analysis (IPCA1/IPCA2). Mean Comparison: Fisher's protected least significant difference (LSD) at 1% and 5% significance levels. AMMI (Additive Main effects and Multiplicative Interaction) model to interpret genotype-by-environment (GxE) interaction. These methods were employed to determine stable genotypes across various testing locations.

Results and Discussion

Combined Analysis of Variance

The of variance (ANOVA) revealed that highly significant ($P < 0.01$) differences among Varieties, and Years for all major traits, including the number of roots per hill, marketable root yield, and total root yield (Table 2). This indicates substantial genetic variability among the tested varieties and a strong influence of the environment on trait expression. The similar finding in multi-environment trials as reported by Mwanga *et al.,* (2017) and Mekonnen *et al.,* (2022). The Varieties x location x Years interaction was also highly significant ($P < 0.01$) for yield parameters, indicating the complex nature of variety performance across different seasons and locations, reinforcing the need for multi-year testing as emphasized by Ngailo *et al.,* (2019) and Shumbulo *et al.,* (2022).

Besides, the genotypes, the environments, and their interaction showed highly significant variation ($P<0.001$) for all evaluated traits of white-fleshed sweet potato. The results also further revealed that the environments (both locations and growing years) on which the experiments were conducted were different from one another in treating the tested sweet potato Varieties. The current result is in close agreement with that of Abewot *et al.,* (2022). Likewise, it also indicates that the responses of the genotypes were varied and vacillated in their trait expression with changes in the environment. All these phenomena evidently established the presence of GEI in this study the present study for different traits of sweet potato genotypes were in agreement with the previous report by different authors (Tigabu *et al.,* 2015; Habtie, 2022).

The Agronomic performance of sweet potato varieties

The mean performance of total storage root yield of six white-fleshed sweet potato varieties across all environments are depicted in Table 3. Hawasa-09 had the highest average total storage root yield (54.71 t ha-^{1}), followed by Tola (47.18 t ha^{-1}) and Adu (43.08 t ha^{-1}), respectively, while local variety was the lowest yielding variety (31.73 t ha^{-1}) (Table 3). Similarly, Mulualem *et al.,* (2022), Abewoy *et al.,* (2022), and Nwankwo *et al.,* (2022) reported a significant difference in marketable storage root yield among sweet potato varieties tested. Moreover, the result of this study was in line with Shiferaw *et al., (*2017), who reported the presence of significant variation between sweet potato varieties for yield and yield-related parameters.

Root yield and related traits of white-fleshed sweet potato Varieties

The combined analyses of variance of root yield and root yield-related traits of all environments revealed that there were highly significant variation ($P<0.01$) among the varieties, environments (year, location, year x location), and variety by environment interaction (genotype x year, genotype x location, and genotype x year x location) (Table 2). Thus, varieties like Hawasa 09, Tola, Barkume and Hawasa 83 had higher root yield over the check variety (Table 3). The root yields of six tested varieties across three locations ranged from 43.91 t ha^{-1} to 69.10 t ha^{-1} with an overall mean of 44.97 t ha^{-1}. The finding is consistent with previous works reported by Bikamo and Ebrhim (2023).

These significant variations of the genotypes, environments, and the genotype by environment interaction indicated that the response of the genotypes were variable and varied in their yield and yield-related traits with change in environment, and these phenomena clearly declared the presence of GEI in this Study.

Storage Root Number per Plant

The mean of storage root number per plant for the varieties is presented in Table 4. Hawasa-09 had the highest root number per plant across environments, with a mean of 11.33, followed by Tola and Adu, which produced 9.79 and 8.17 numbers of roots per plant, respectively. The lowest mean root number per plant of 4.50 was recorded for Awassa-83. The result of this study was in line with Chulda *et al.,* (2022), who reported the presence of significant variation between sweet potato varieties for yield and yield-related parameters.

Additive main effect and multiplicative interaction (AMMI-2) bi-plot analysis

The AMMI analysis for root yield showed significant differences for genotypes, environments, and genotype-by-environment interactions. This was in agreement with Getachew *et al.,* (2020), suggesting that the G×E pattern is collected in the first two principal components of analysis. The factors explained showed that the WFSP genotype's root yield was affected by environment (63.16%), genotype (8.13%), and GEI (24.88%).

Table.1 Description of white-fleshed sweet potato varieties evaluated during the 2023-2024 cropping season

Varieties	Year release	Breeder source
Hawasa-09	2017	Hawasa Agricultural Research center/SARI
Barkume	2007	Haramaya University
Tola	2012	Bako Agricultural Research center/IQQO
Adu	2007	Haramaya University
Hawasa-83	1998	Hawasa Agricultural Research center/SARI
Local (Damme)	-	-

Table.2 Mean squares for yield and related traits of white-fleshed sweet potato varieties across tested locations

SV	DF	RL	RD	NRY	MRY	UMRY	TRY	ARW
Rep	2	7.69ns	5.84ns	12.51ns	63.85ns	0.07ns	62.92ns	0.12ns
Var	5	4.39ns	4.68ns	161.06**	789.66**	31.17**	1021.14**	2.73**
Loc	2	115.43**	96.61**	48.93**	3853.66**	6796.79ns	6922.52**	25.81**
Yr(Y)	1	1002.66**	17.47**	14.82ns	292.45**	5430.66**	3202.64**	0.17ns
Var x Loc	10	1.149ns	9.15**	10.68ns	664.62**	35.15**	604.09**	3.23**
Var x Yr	5	0.49*	5.06**	2.79ns	466.99**	32.91**	629.94**	2.03**
Var x L x Y	10	98.55**	22.32**	21.04**	604.35**	933.04**	2410.51**	4.43**
Error	70	0.48	0.44	5.34	22.52	3.41	32.58	0.2

SV=Source of Variation, DF= degree of freedom, DM=Days to maturity, RL=Root length, RD=Root Diameter, MY=Marketable Root yield, UMRY=Unmarketable root Yield, TRY=Total Root Yield, ARW=Average root weight, *=significant differences,**= Highly significant and ns=Non-significant

Table.3 Combined mean Root yield (t ha^{-1}) of White-fleshed sweet potato tested at Bedele, Dabo Hana, and Gechi districts for two years (2023-2024

Varieties	Bedele			Dabo			Gechi			Over all combined
	2023	2024	Combined	2023	2024	Combine	2023	2024	Combine	
Hawasa-09	69.10a	59.13a	64.12a	44.52a	74.67a	60.59a	49.58a	42.02b	48.27a	54.71a
Barkume	52.63b	42.78b-d	47.72b	27.15b	49.98b	43.57b	32.19b	66.07a	51.61a	40.10c
Tola	62.33a	39.92cd	51.13b	36.85a	54.30b	45.58b	41.90a	63.18a	55.02a	47.18b
Adu	43.91c	46.77bc	45.34b	18.43c	61.29b	39.86b	23.24c	67.39a	47.91a	43.08b
Hawasa-83	52.47b	51.273ba	51.87b	27.10b	50.36b	38.73b	32.04b	21.07c	29.08b	39.57c
Local (Damme)	51.66b	33.91d	42.79b	26.18b	48.61b	37.40b	31.20b	23.40c	29.79b	31.73d
CV (%)	6.57	17.05	11.81	12.73	9.74	11.24	10.76	10.15	11.44	27.57
LSD (0.05)	7.84	10.81	9.33	7.44	15.78	11.61	8.05	8.52	7.98	7.94
P-Value	**	**	**	**	**	**	**	**	**	**

LSD (0.05)=Least significant differences and CV (%)= coefficient of variation and **=Highly significant

Table.4 AMMI Analysis of Variance of Six Environments during 2023-2024 cropping

Source of variation	DF	SS	MS	TSS (%)	GEI %	Cumulative (%)
Genotypes (G)	5	5106	1021**	8.13		
Environments (E)	5	39670	7934**	63.16		
Block (E)	12	190	16ns			
Interactions	25	15623	625**	24.88		
IPCA 1	9	8868	985**		56.76	56.78
IPCA 2	7	6080	869**		38.92	95.68
Error	60	2217	37			
Total	107	62806	587			

Table.5 Mean root yield (t ha^{-1}), AMMI Stability Values, and Yield stability index for WFSP varieties

Genotype	Root Yield	RY	IPCA1	IPCA2	ASV	RASV	YSI
Adu	57.58	3	-3.56633	-1.94781	5.55	3	6
Barkume	50.2	4	0.67244	-4.6326	4.74	2	6
Hawasa-09	64.71	1	-0.69766	2.57932	3.75	1	2
Hawasa-83	49.57	5	-2.36259	0.56166	3.75	1	6
Tola	58.07	2	0.02708	3.57469	3.75	1	3
Local (Damme)	43.72	4	5.92707	-0.13526	8.65	4	8

Key: RY = Rank of Yield, IPCA1 = interaction principal component analysis axis 1and IPCA2 = interaction principal component analysis axis 2, ASV = AMMI stability value, RASV = Rank of AMMI stability value, YSSI = Rank genotype selection index, means = average genotype by environment

Table.6 The AMMI model‘s best white-fleshed sweet potato varieties selection per environment

Environment	Root Yield (t ha^{-1})	IPCA1 Score	Table of the first four AMMI selections per environment			
			1	2	3	4
Dabo-2024	91.18	5.252	Hawasa -09	Barkume	Tola	Adu
Gechi-2023	40.07	0.600	Hawasa -09	Tola	Adu	Hawasa -83
Dabo-2023	40.02	0.597	Hawasa -09	Tola	Adu	Hawasa-83
Bedele-2023	65.50	0.597	Hawasa -09	Tola	Adu	Hawasa -83
Gechi-2024	37.19	-2.856	Adu	Barkume	Hawasa -83	Hawasa-09
Bedele-2024	49.89	-4.191	Adu	Tola	Hawasa -83	Local (Damme)

Figure.1 GGE-biplot based on the ranking of varieties for root yield relative to stable genotype

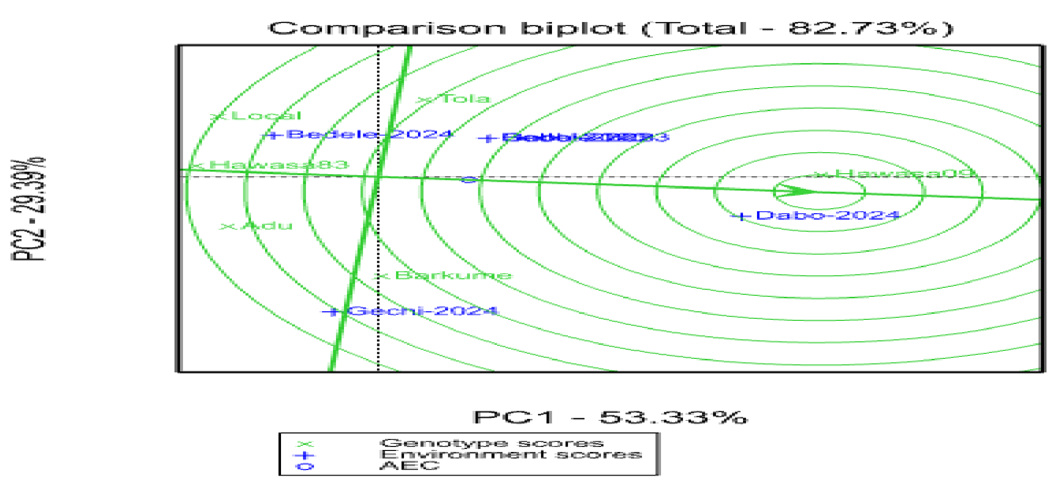
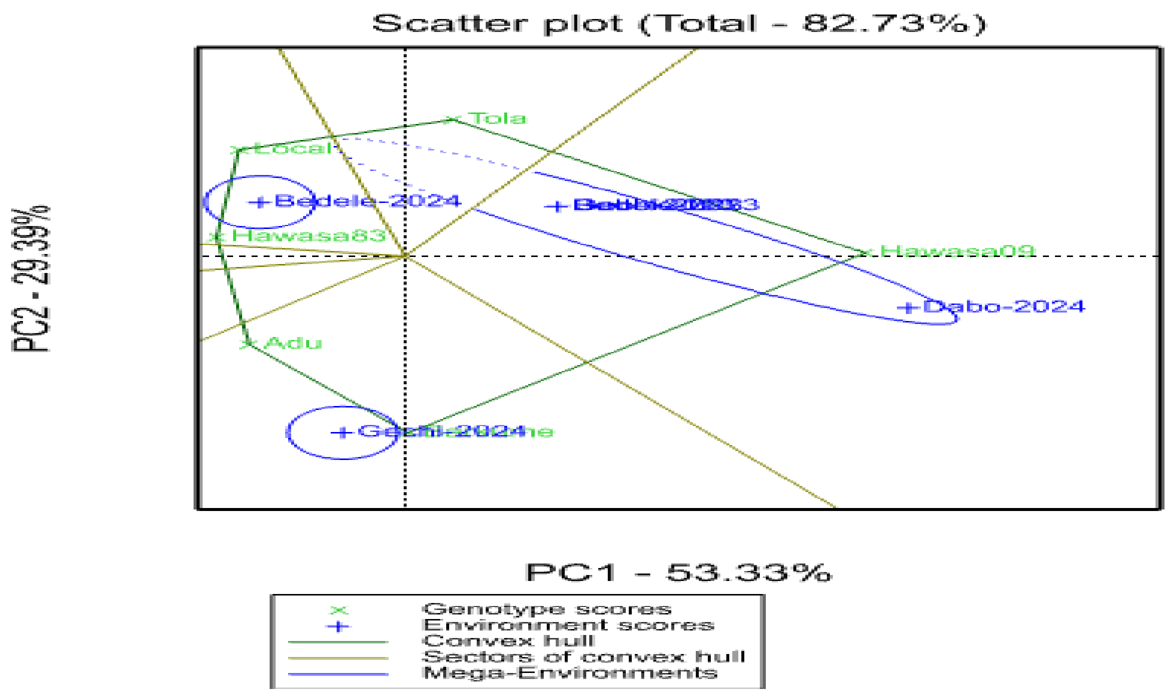


Figure.2 Polygon view of genotype by environment interaction for White fleshed sweet potato-fleshed varieties.



The highly significant effect of location on yield was reported by Wariboko Wariboko and Ogidi (2014), Getachew (2020), and Gobena *et al.,* (2022), and on white sweet potato. Moreover, the significant G x E interaction indicated the differential response of genotypes grown across environments was described by Gurmu (2019) on white-fleshed sweet potato. These findings are consistent with the use of AMMI for identifying stable sweet potato genotypes, as demonstrated by Asfaw *et al.,* (2023).

AMMI Stability Value (ASV) and Genotype Selection Index (GSI)

In ASV, the genotype with the least ASV value is the most stable, whereas those that have the highest ASV are considered unstable (Gurmu, 2019) However, stability needs to be considered in combination with yield. While the Genotype Selection Index (GSI) was utilized to further identify stable genotypes with better yield performance. Genotypes with the lowest ASV values are identified as the shortest and considered the most stable. Accordingly, varieties (Hawasa-09) appeared to be among those showing low ASV and were the most stable, followed by Tola. In contrast, Local and Adu varieties indicated the highest ASV and were thus considered unstable. The result was similar to the finding of Mulualem *et al.,* (2022).

The four best genotypes selected by the AMMI model

The four best varieties selected by the AMMI model in different environments are presented in Table 6. The first highest-yielding variety (Hawasa-09) selected among the four best AMMI selections in five environments (Dabo Hana-2024, Gechi-2023, Dabo Hana-2023, and Bedele-2024) is favorable. The selection of genotype in respective environments is an indication of the best adaptation of the genotypes to those particular environments. The selection of genotypes in respective environments is an indication of the best adaptation of genotypes in relation to the environments. Better selected in most environments, as a higher share indicated it had the best adaptation. The other genotypes that were selected did not show a distinct pattern of adaptation and were more specifically adapted to either higher or lower yielding environments (Table 6).

Ranking of genotypes based on mean and stability performance

Genotypes that fall in the central (concentric) circle are considered ideal stable genotypes. A genotype is more desirable if it is located closer to the ideal genotype.

Thus, using the ideal genotype as the center, concentric circles were drawn to help visualize the distance between each genotype and the ideal genotype. Thus, Hawassa - 09 and Tola were the stable varieties, with the highest mean grain yield. A similar result was reported by other researchers (Birhanu *et al.,* 2014; Ettana *et al.,* 2025).

Discriminating ability and representativeness of environments

GGE biplot also helps to identify representative environments for the mega-environment. An environment that is found in the concentric circle or near the concentric circle is an ideal Environment. Thus, Dabo Hana-2024, Bedele-2023, and Gechi-2024 were identified as the most discriminating environments. In agreement with this (Mekonnen *et al.,* 2022) on Sweet potato.

GGE bi-plot Analysis '"Which-Won-Where'" Patterns of Genotypes

GGE biplot for visual observation to understand which varieties best performed in which environment. The winning genotypes for each sector are those placed at the vertex. Therefore, Hawasa 09 was the winner at (Dabo Hana-2024 and Bedele -2023). Similar findings in the stability analysis of white fleshed sweet potato OFSP were also reported by Mekonnen *et al.,* (2022), who identified genotypes of WFSP that were stable and produced high yields.

Conclusion and Recommendation

Crop yield is a complex genotype that is influenced by trait along with the environment, either directly or indirectly. The study successfully identified significant genetic variation and a strong genotype-by-environment interaction influencing the performance of white-fleshed sweet potato varieties in the Buno Bedele Zone. The AMMI analysis provided a clear insight into the stability and adaptation patterns of the varieties, which is crucial for making targeted recommendations. Based on the consistent high-yield performance and stability across multiple environments, as confirmed by both combined means and AMMI analysis, Hawasa-09 and Tola are recommended for demonstration and promotion to farmers across the Buno Bedele Zone due to their high yield and stability.

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