Int.J.Curr.Res.Aca.Rev.2025; 13(5): 47-60

EXCELLENT PUBLISHERS

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 13 Number 5 (May-2025)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2025.1305.007

Genotype by Environment Interaction and Stability Analysis of Marketable Tuber Yield of Potato (*Solanum tuberosum* L.) Genotypes in Guji Zone, Southern Oromia, Ethiopia

Arega Amdie*, Solomon Teshoma and Miressa Mitiku

Oromia Agricultural Research Institute (IQQO), Bore Agricultural Research Center (BoARC)

**Corresponding author*

Abstract

In multi-environment trial, considering both the stability and marketable tuber yield is very important. This *experiment* was conducted with the objective of to determine the magnitude of G x E interaction and select stable, high yielding, resistant reaction to late blight and specifically performed genotypes for target environments. A total of 12 Potato genotypes including 2 standard checks were evaluated at six locations during 2022/23 and 2023/24 'Belg' cropping seasons. The genotypes were arranged in Randomized Complete Block Design and replicated three times. Combined ANOVA, AMMI and GGE bi-plot models were used to analyze the data. Both AMMI and GGE biplot analyses identified that genotypes G-3(CIP-313033.06) and G-7(CIP-395126.6) were confirmed as widely adapted genotypes with likewise recorded higher marketable tuber yield of 47.80 t/ha and 41.98 t/ha, respectively. The significant effect of genotype x environment interaction on marketable tuber yield, dry matter, specific gravity and starch content suggests the importance of testing genotypes across locations over years to benefit producers, processors and other consumers. Accordingly, genotypes were superior than the standard checks with marketable tuber yield advantage of 50.88% and 32.50%, respectively and were recommended as candidate varieties for further evaluation and release.

Article Info

Received: 20 March 2025
Accepted: 25 April 2025
Available Online: 20 May 2025

Keywords

Adapted, AMMI, Genetic-environment interactions, Stability, Yield advantage.

Introduction

Potato (*Solanum tuberosum* L.) belongs to the family *Solanaceae* and genus *Solanum* (Thompson and Kelly, 1972). It is one of the vital tuber crops in terms of food security for a growing population and increased hunger rates (CIP, 2018).

Among root and tuber crops, potato is an important food and cash crop in Eastern and Central Africa, playing a major role in national food and nutrition security, poverty alleviation and income generation, and provides employment in the production, processing and marketing sub-sectors (Abebe, 2019). Potato can provide more carbohydrates, proteins, minerals, and vitamins per unit area of land and time as compared to other potential food crops (Zaheer and Akhtar, 2016). On average, potato tubers contain 77% water, 20% carbohydrates, and less than 3% of proteins, dietary fiber, minerals, vitamins and other compounds (Zaheer and Akhtar, 2016). It is also regarded as a high potential food security crop because of its ability to produce high yield and quality product per unit input with a shorter crop cycle (mostly < 120 days) than major cereal crops (maize) (Adane *et al.,* 2010). It is an important crop, widely grown both for food and cash income by smallholder farmers in high

altitude 1600-2800masl (FAO, 2009). The potential for high yield, early maturity, and excellent food value give the potato great potential for improving food security, increasing household income, and reducing poverty (Devaux *et al.,* 2014). It is also considered to be the world's fourth important food crop after maize, wheat, and rice because of its high yield potential and nutritive value (Kumar *et al.,* 2013; Pandey *et al.,* 2014) and the crop is still by far the highest yielding compared to maize, rice, soy and wheat (FAO, 2018). Its origin in the high Andes of South America and it was introduced to Ethiopia in 1858 by the German botanist Shimper (Berga *et al.,* 1992). Generally, Potato requires altitude between 1800 to 2500 (Bezabih and Mengistu, 2011), optimum soil temperature 16-19°C (Anonymous, 2004), high rainfall ranging between 1000 and 1500 mm per year (Gusha, 2014), temperate climates (Humans, 2003) Potatoes grow best in loose, well-drained, non-crusting, sandy loam or loam soils with high organic matter content and pH between 5.5 and 6.5 (Martha and Ann, 2017). In Eastern Africa, Ethiopia is the major producer of potato, and 70% of the arable land is suitable for potato cultivation b/c of suitable agro ecology but the average national yield of potato 16.687 tha^{-1} (CSA, 2022), the average yield of potato yield (29.4tha^{-1}) in Guji zone (Dembi *et al.,* 2017) also it is very low as compared to the yield in developed countries 30 to 40 tha^{-1}(FAO, 2000). This is due to a number of production problems that account for low regional as well as national yield having been identified. These include the many diverse and complex biotic and abiotic factors are contributing for low productivity of potato including inappropriate agronomic practices, prevalence of disease and insect pests, poor soil fertility management, high cost of seed tubers, inadequate storage and marketing facilities (Menza *et al.,* 2014). Potato varieties in cultivation were not able to meet the requirements of growers in terms of yield, late blight resistance, and quality, among others (Gebremedhin *et al.,* 2001).

Potato is one of the most important tuber crops grown in Guji zone, the southern parts of Oromia region. The highlands of this zone have vast plain arable land suitable for production of tuber crops and vegetables both under rain fed and irrigation condition. However, lack of high yielding and resistance to late blight varieties and quality planting materials constrained potato production small and large scale farms in the high land areas of Guji zone. The existing recommended potato varieties were found susceptible to late blight and become low yielder. Therefore, there is an urgent need to replace these varieties by developing better varieties, wider adaptable, high yielding, and early-maturing and disease-resistant potato varieties with characteristics desired by consumers and processors for the study area. Genotype and environment interactions are correlated with the performance of genotypes that indicate stability when planted in various environments. Ruswandi *et al.,* (2008) reported selection of high-efficiency and quality genotypes based on multi environment testing. Regarding agricultural problems from genotype-by-environment interaction, there exist two basic options, one aimed at the genotypes, and the other at the environments (Ceccarelli, 1989; Simmonds, 1991; Zavala-Garcia *et al.,* 1992). Therefore, this research was conducted with the following objective:- to develop a late blight tolerant, high-yielding, widely-adapted, and stable potato variety for Guji zones and having similar agro-ecologies in the country.

Materials and Methods

Description of the Experimental sites

The field experiment was carried out under rain fed conditions during the 2022 and 2023 cropping seasons at Bore on station, Anna sora and Arda jila on-farm in the Guji zone, Southern Ethiopia. The first experimental were located at Bore research site at the distance of about 8 km north of the town of Bore in Songo Bericha '*Kebele'* just on the side of the main road to Addis Ababa via Awassa town. Geographically, the experimental site is situated at the latitude of 06°23'55''N and longitude of 38°35'5''E at an altitude of 2728 m above sea level. The major soil type is clay in texture and strongly acidic with pH value of 5.1 (Arega, 2020). The second experimental site was located at Anna sora at the distance of about 30 km East of the town of Bore in Raya Boda '*Kebele'* just on the side of the main road to Addis Ababa via Adola town.

The second experimental site was located at Anna sora at the distance of about 25 km East of the town of Bore in Raya Boda '*Kebele'* just on the side of the main road to Addis Ababa via Adola town. Geographically, the experimental site is situated at the latitude of 06°10'N and longitude of 380°380'E at an altitude of 2451 m above sea level and soil type is Clay/Nitosols (Tekalign *et al.,* 2019). The third experimental site was located at Arda jila district at the distance of about 45 km East of the town of Bore in Raya Boda '*Kebele'* just on the side of the main road to Addis Ababa via Adola town. Geographically, the experimental site is situated at an altitude of 2250 m above sea level and soil type is Clay.

Treatments and Experimental Design

About twelve (12) potato genotypes were evaluated for wider locations in high and midland areas of the Guji zone along with two (Gudane and Jalene) standard checks. The genotypes were arranged in a randomized completed block design (RCBD) with three replications. A plot size of 3 m x 3 m (9 m2) and spacing of 75 cm and 30 cm between rows and plants, respectively, as well as four rows per plot and 40 tubers per plot, were used. Fertilizer rates of 200 kg ha^{-1} NPSB and 100 kg ha^{-1} urea. Urea was applied in the split. We followed the crop's recommendation for all pertinent management practices.

Data Collection

Phenology, Growth, tuber yield and yield components, internal quality attributes, and late blight were collected:- Days to 50% flowering, Days to 90% maturity, Plant height (cm), Number of stem per plant, Number of tuber per hill, Weight of tubers per plant (g), Marketable tuber yield (t ha^{-1}), Unmarketable tuber yield (t ha^{-1}), and Total tuber yield (t ha^{-1}). Number of tubers per plant, Dry matter (%), Specific gravity (gcm^{-3}), Starch (%), and Late blight (%) were collected.

The dry matter in percent was calculated according to Williams and Woodbury (1968) as follows

$$\text{Dry matter (\%)} = \frac{\text{Intial Weight of Sample (g)}}{\text{Weight of Sample after drying(g)}} \text{X100 (OR)}$$

Dry matter (%) = -214.9206 + 218.1852 (specific gravity) (Kleinkopf *et al.,* 1987)

The specific gravity of tubers was calculated using the following formula (Kleinkopf *et al.,* 1987).

$$\text{Specific gravity } (gcm^{-3}) = \frac{\text{Weight in Air}}{\text{Weight in Air} - \text{Weight in Water}} \text{X100}$$

Total starch content (g/100g) was estimated from specific gravity.

Starch (%) = 17.546 + 199.07(specific gravity-1.0988) (Talburt and Smith, 1959)

Late blight disease severity and incidence assessment begins at the day of first symptoms appeared on susceptible plots every week 7 days interval until the majority of the plots of plant attained physiological maturity. The disease incidence (1-9 CIP Scale) was recorded as described by Henfling (1987) and CIP (2006) guideline.

Data Analysis

Field data were analyzed using SAS software for the data following the standard procedures outlined by Gomez and Gomez (1984). GGE bi- plots and AMMI Analysis of Variance were performed using Gen Stat 18th edition statistical package. Mean comparisons among the treatment were done using Fisher's unprotected least significant difference (LSD) test at 5% level of significant.

AMMI Analysis

The potato managed data were subjected to combined analysis of variance and AMMI analysis, which is a combination of analysis of variance and multiplication effect analysis. Multiplication effect analysis was used to partition G × E deviations into different Interaction Principal Component Axes (IPCA), which were tested for statistical significance through ANOVA. To determine the G ×E interaction for yield parameters, AMMI and GGE bi-plot analyses were performed. The following AMMI model was used (Gauch, 1992).

AMMI Stability Value

AMMI stability value was calculated in the excel spread sheet using the formula developed by Purchase *et al.,* (1997).

$$ASV = \sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCAI\ Score)\right]2 + [IPCA2\ score]2}$$

Where, $\frac{SSIPCA1}{SSIPCA2}$ is the weight given to the IPCA value by dividing the IPCA1 sum of squares by the IPCA2 sum of square.

Genotype Selection Index

Genotype selection index was also calculated by the formula suggested by (Farshadfar, 2008). A genotype with the leas t GSI is considered as the most stable (Farshadfar, 2008).

$GSI_i = RASV_i + RY_i$

where, RASV is the rank value of genotypes for AMMI stability value and RY is the rank value of genotypes for marketable tuber yield. A genotype with the least GSI is considered as the most stable (Farshadfar, 2008).

GGE Biplot Analysis

The most recent method, GGE biplot model, provides breeders a more complete and visual evaluation of all aspects of the data by creating a biplot that simultaneously represents mean performance and stability, as well as identifying mega-environments (Ding *et al.,* 2007, Yan and Kang, 2007).

To analysis stability and identify superior genotype across environment, GGE bi-plot analysis were conducted. GGE biplot best identifies G x E interaction pattern of data and clearly shows which variety performs best in which environment.

$$\bar{Y}ij - \mu i - \beta j = \sum_{k=1}^{t} \lambda \chi^{a} ik \gamma jk + \sum ij$$

where; $\bar{Y}ij$= the performance of genotype i in environment j, μ = the grand mean, βj= the main effect environment j, k = the number of Principal Components (PC); λk = singular value of the kth PC; and α *ik* and γjk = the scores of ith genotype and jth environment, respectively for PC k; εij = the residual associated with genotype i in the environment j. Usually only the first two PCs are used especially if they account for the major portion of the G x E interaction.

Results and Discussion

The combined analysis of variance revealed that highly significant differences ($p \leq 0.01$) were observed among the genotypes, year, genotypes interaction year, genotypes interaction locations and genotype interaction year and locations (Table 2). The presence of significant genotype, location, and year interaction indicates that genotypes responded differently to the variation environmental conditions.

Additive Main Effect and Multiplicative Interaction (AMMI)

AMMI analyses revealed significant ($P < 0.01$) on genotype, environment and genotype by environment interaction with respect to marketable tuber yield. This is indicating that genotypes responded differently to the traits in each environment (Table 3). The ANOVA using the AMMI model the contribution of genotype, environment and G x E interaction about 34.74%, 5.17% and 37.91% respectively, to the total variation observed in potato yield (Table 2).

This result coincides with findings of previous studies (Papastylianou *et al.,* 2021; Haile and Kebede, 2021; Abou-Khater *et al.,* 2022). Partitioning the G x E interaction by AMMI analysis showed that the first Principal Component Axis (IPCA1), second Principal Component Axis (IPCA2), and third Principal Component Axis (IPCA3) were significant one; the first IPCA explained 62.82%, second IPCA explained 16.58% and the third IPCA explained 13.86%.The three PCA1, PCA2, and PCA3) totally 93.36% of G x E cumulative variation.

Haynes *et al.,* (1998); Yan and Kang (2003) reported that if the percentage of the first two principal components would explain more than 50% of the total variation, the biplot would be a good alternative to study the genotype by environment interaction.

The presence of significant GxE interaction indicates that genotypes responded differently to the variation environmental condition. The existences of significant G x E interaction in potato for tuber yield (Hassanpanah, 2010).

Phenology, Growth and Yield Components Mean Performances

These two years repeated over location analysis of variance revealed that highly significant differences ($p \leq 0.01$) for days to flowering, days to phenological maturity, plant height, stem number per plant, number of tuber per plant, and tuber weight.

The highest combined mean performance of tuber number per hill was recorded for the G-07 (CIP-313022.07) 11.31 followed and G-3 (CIP-313033.06) 11.14 whereas the lowest mean was obtained from the G-2 (CIP-396009.239) 6.78 (Table 4).

The significant differences in days to 50% flowering, 90% maturity, plant height, stem number per plant, tuber number per hill growth, and tuber weight of the genotypes across year and locations could therefore, be attributed to differences in the genetic potential of the tested materials, differences in agro-ecological conditions and also genotypes x environmental

interactions. Similar results were reported by Nakitandwe *et al.,* (2005). The presence of significant differences for days to flowering and maturity among potato genotypes have been reported by Lemma *et al.,* (2020) over locations in Ethiopia.

Marketable tuber yield and Disease Mean Performances

These two years repeated over location analysis of variance revealed that highly significant differences ($p \leq 0.01$) for marketable tuber yield, and disease severity. The highest combined mean performance of marketable tuber yield was recorded for the G-3(CIP-313033.06) 47.80 t/ha followed and G-7 (CIP-395126.6) 41.98 t/ha whereas the lowest mean was obtained from the G-211(CIP-313024.211) 24.63 t/ha also, the G-3(CIP-313033.06) less late blight attack followed and G-7 (CIP-395126.6)potato late blight disease (Table 5).

Marketable yield differences between these genotypes may be due to their genetic makeup, agro-ecological conditions, resistance to disease, weight of tubers per plant, numbers of tuber per plant etc. This result is in agreement with that of Mesifn *et al.,* (2022) who reported that yield differences among genotypes were attributed both by the inherent yield potential of genotypes and growing environment as well as the interaction of genotype x environment.

Unmarketable and Total tuber yield and Quality Attributes Mean Performances

These two years repeated over location analysis of variance revealed that highly significant differences ($p \leq 0.01$) for Unmarketable tuber yield, Total tuber yield, Dry matter content (%), Specific gravity (gcm^3), and Starch Content (%).

The highest combined mean performance of total tuber yield was recorded for the G-3(CIP-313033.06) 52.04 t/ha followed and G-7 (CIP-395126.6) 45.90 t/ha whereas the lowest mean was obtained from the G-6(CIP-313024.211) 28.42 t/ha (Table 6).

The yield differences between these genotypes may be due to their genetic makeup, agro-ecological conditions, resistance to disease, weight of tubers per plant, numbers of tuber per plant etc.

This result is in agreement with that of Mesifn *et al.,* (2022) who reported that yield differences among genotypes were attributed both by the inherent yield potential of genotypes and growing environment as well as the interaction of genotype x environment.

AMMI Stability Value (ASV)

AMMI stability values revealed variations in yield stability among the 14 potato genotypes (Table 7). In the ASV method, a genotype with high pooled mean, small IPCA1score and the least ASV score is the most stable. Accordingly, G-12(CIP-313037.312), and G-7(CIP-395126.6) were the only genotypes that were highly stable, with ASV value of 1.15 and 1.63, respectively.

However, G-12 (CIP-313037.312) was showed lower yield performance than G-7(CIP-395126.6) and G-3(CIP-313033.06). Therefore, stable with higher yield genotypes can be promoted for further evaluation and for wider production.

The AMMI model does not make provision for a quantitative stability measure. Such a measure is essential in order to quantify and rank genotypes according to their yield stability. In fact, ASV is the distance from zero in a two-dimensional scatter gram of IPCA1 scores against IPCA2 scores. Since the IPCA1 score contributed more to G × E interaction sum of square, it has to be weighted by the proportional difference between IPCA1 and IPCA2 scores to compensate for the relative contribution of IPCA1 and IPCA2 to the total G × E interaction sum of squares.

Genotype Selection Index (GSI)

Genotype Selection Index (GSI) was utilized to further identify stable genotypes with better yield performance. Generally, the G-3 (CIP-313033.06 and G-7(CIP-395126.6) were considered as the two stable genotypes with highest marketable tuber yield(Table 7).

Additive Main Effect and Multiplicative Interaction (AMMI 2) Bi-plot Analysis

The AMMI 2 bi-plot analysis was conducted by plotting IPCA 1 scores against IPCA 2 scores for genotypes and environments. The AMMI 2 bi-plot analyses of marketable tuber yield of the 14 genotypes evaluated in six locations are shown in Figure 1. G-7(CIP-395126.6), G-12(CIP-313037.312), and G-3(CIP-313033.06) had broad adaptability across the environments as they were located closer to the center of the bi-plot.

Table.1 List and description of potato genotypes used in the study

SNo.	Genotype Code	Genotype name
1	G-1	CIP-313022.75
2	G-2	CIP-396009.239
3	G-3	CIP-313033.06
4	G-4	CIP-395037.12
5	G-5	CIP-313022.117
6	G-6	CIP-313024.211
7	G-7	CIP-395126.6
8	G-8	CIP-313022.07
9	G-9	CIP-313022.118
10	G-10	CIP-308538.213
11	G-11	CIP-313039.127
12	G-12	CIP-313037.312
13	Jalene	Jalene
14	Gudane	Gudane

Table.2 Combined analysis of variance for mean marketable tuber yield of potato tested at three locations (Bore, Ana sora and Arda jila) for two years (2022/23-2023/24).

Source of variation	DF	SS	MS	P-Value
Blocks(B)	2	364.87	182.04	0.0048
Genotype (G)	13	9173.03	705.62	<.0001
Location(L)	2	142.40	71.20	0.119
Year(Y)	1	771.75	771.75	<.0001
G*L	26	2705.32	104.05	<.0001
G*Y	13	5264.80	404.98	<.0001
L*Y	2	451.76	225.88	0.0014
G*L*Y	26	2040.18	78.47	0.0005

Table.3 AMMI ANOVA for Marketable tuber yield of potato genotypes evaluated at 6 locations over 2022 to 2023 cropping seasons

Source of variation	Df	SS	MS	Total variation explained to SS (%)	GxE explained (%)	G x E cumulative
Blocks (B)	12	901	75**			
Environments (E)	5	1366	273.1**	5.17		
Genotypes (G)	13	9174	705.7**	34.74		
G x E Interaction	65	10010	154**	37.91		
IPCA1	17	6288	369.9**		62.82	93.36
IPCA2	15	1660	110.7**		16.58	
IPCA3	13	1388	106.8**		13.86	
Residuals	9	297	33ns			
Total	251	26405	105.2			

*,**: Significant and highly significant at $\leq$ 0.05 and $\leq$ 0.01 probability levels, respectively; DF: Degrees of Freedom, SS: Sum of Square, MS: Means of Square, C.V: Coefficient of Variation

Table.4 Agronomic traits performance of 14 Potato genotypes over locations for 2022-2023 cropping seasons

Genotypes	Days to		Plant height (cm)	Steam number plant^{-1}	Tuber number hill^{-1}	Tuber weight (g/tuber)
	Flowering	Maturity				
CIP-313022.75	57.77cb	104.00bc	66.00h	6.12b	8.99def	78.21ef
CIP-396009.239	52.22g	104.22b	88.63a	5.28de	6.78g	103.58bc
CIP-313033.06	62.11a	109.72a	78.97de	5.88bcd	11.14ab	117.60ab
CIP-395037.12	56.22ed	101.94b-e	84.17bc	4.39f	7.64efg	86.78c-f
CIP-313022.117	55.88ef	109.44a	72.84g	5.38b-e	7.67efg	99.37cd
CIP-313024.211	56.11ef	102.77bcd	74.13fg	5.29de	7.61fg	88.60c-f
CIP-395126.6	58.11b	98.83ef	86.38ab	5.03ef	9.10cd	127.11a
CIP-313022.07	61.83a	97.50f	73.09fg	5.83bcd	11.31a	75.31f
CIP-313022.118	55.61ef	108.66a	76.07efg	5.57b-e	9.70cd	85.75def
CIP-308538.213	58.00b	102.38bcd	78.82de	5.36cde	9.74bcd	83.86def
CIP-313039.127	61.77a	104.00bc	61.98h	6.04bc	8.94def	92.93cde
CIP-313037.312	56.66cde	100.77c-f	77.28def	5.69b-e	9.55cd	96.44cd
Jalene	54.88f	99.88def	76.92d-g	6.89a	10.47abc	84.05def
Gudane	57.44bcd	103.83bc	81.03cd	5.85bcd	9.04de	94.45cde
Mean	57.47	103.42	76.88	15.62	9.12	93.86
LSD(5%)	1.32	3.32	4.37	0.73	1.41	16.96
CV(%)	3.51	4.88	8.63	19.82	23.49	27.46

Table.5 Potato genotypes performance for Marketable tuber yield s (tons/ha) across locations and over year

Genotypes	Test Environments						Overall means	(%) Yield advantages	Diseases severity (1-9 scale)
	2022			2023					
	Bore	Ana sora	Arda jila	Bore	Ana sora	Arda jila			
CIP-313022.75	13.36d	29.33def	28.14bc	27.46de	30.75b-f	26.08def	25.86e		7.16fgh
CIP-396009.239	22.78bc	20.21g	25.78cd	35.12bcd	30.26b-f	32.21de	27.73de		26.49bc
CIP-313033.06	48.48.13a	45.53ab	45.78a	45.12ab	50.61a	51.66a	47.80a	50.88	1.38h
CIP-395037.12	27.47b	21.13fg	20.52cd	33.22cde	28.66c-d	23.83ef	25.81e		12.51efg
CIP-313022.117	24.59b	29.16def	25.66cd	41.08abc	35.29b-e	29.02def	30.80cd		3.88h
CIP-313024.211	1589cd	30.54de	25.59cd	23.19e	28.12def	24.41def	24.63e		22.28cd
CIP-395126.6	43.18a	47.92a	41.47a	37.09bcd	40.68abc	41.54bc	41.98b	32.50	14.72def
CIP-313022.07	27.11b	40.68abc	37.02ab	23.50e	20.08f	30.68de	29.85cd		76.09a
CIP-313022.118	27.86b	26.85efg	20.43cd	36.57bcd	31.78b-f	43.00ab	31.08cd		5.54gh
CIP-308538.213	20.73bc	27.96efg	29.15bc	48.48a	41.19ab	20.88f	31.40cd		19.64cde
CIP-313039.127	16.43cd	30.29de	23.21cd	32.14cde	39.90a-d	41.39bc	30.56cd		17.83de
CIP-313037.312	42.05a	34.94cde	45.13a	23.24e	22.00f	33.04cd	33.40c		30.84b
Jalene	26.64b	37.09bcd	42.20a	28.93de	23.68ef	31.51de	31.68c		32.46b
Gudane	23.01bc	27.11efg	18.46d	44.62ab	38.28bcd	33.13cd	30.77cd		27.11bc
Mean	27.09	32.05	30.61	34.27	32.95	33.03	31.66		21.27
LSD (5%)	6.54	8.93	8.93	10.68	12.02	8.72	3.79		7.98
CV (%)	14.38	16.59	17.38	18.56	21.73	15.73	18.16		5.71

MTY= Marketable tuber yield(MTYC-I(40-60mm) + MTYC-II(20-40mm) (tha^{-1}), and disease severity scored using 1-9 scoring scales and percentage values transformed by Arc Sine before statistical analysis

Table.6 Unmarketable tuber yield, total tuber yield, and tuber internal quality traits performance of 14 Potato genotypes over locations for 2022-2023 cropping seasons

Genotypes	Unmarketable tuber yield	Total tuber yield	Dry matter content (%)	Specific gravity(gcm^3)	Starch Content (%)
CIP-313022.75	4.54cde	30.39d	20.55abc	1.081abc	18.07abc
CIP-396009.239	2.32g	30.06d	20.51abc	1.081abc	18.40ab
CIP-313033.06	4.22de	52.04a	20.30abc	1.080abc	17.54cd
CIP-395037.12	2.86fg	28.68d	18.83c	1.073dc	16.50c
CIP-313022.117	3.70ef	34.51d	21.13a	1.084a	18.91ab
CIP-313024.211	3.79ef	28.42d	21.09ab	1.083ab	17.62bc
CIP-395126.6	3.92def	45.90b	20.45abc	1.081abc	17.56c
CIP-313022.07	7.14a	36.99c	19.83a-d	1.077a-d	17.35bc
CIP-313022.118	5.08bcd	36.16c	20.51abc	1.081abc	18.45ab
CIP-308538.213	4.24de	35.64c	19.70a-d	1.077a-d	17.36bc
CIP-313039.127	5.42bc	35.98c	19.37bcd	1.075bcd	18.10ab
CIP-313037.312	4.02def	37.42c	18.47c	1.071d	17.94abc
Jalene	5.69bc	37.37c	19.69a-d	1.077a-d	19.62a
Gudane	6.18ab	36.95c	19.63a-d	1.077a-d	17.49bc
Mean	4.51	36.18	20.00	1.07	17.91
LSD(5%)	1.17	3.74	1.73	0.008	1.70
CV(%)	39.64	15.72	13.19	1.16	14.43

UnMTY(t ha^{-1}) = Unmarketable tuber yield (<200mm, isect attacked, cracked, diseased, deformed) (t ha^{-1}), TTY= Total tuber yield(t ha^{-1}), DMC= Dry matter content (%), SG= Specific gravity(gcm^3), & SC= Starch Content (%).

Table.7 The marketable tuber yield, AMMI stability value (ASV), Genotype selection index (GSI) and principal component axis (IPCA).

Genotypes	Marketable tuber Yield t/ha	Rank	IPCA1 score	IPCA2 Score	ASV	Rank	GSI	Rank	Overall Rank
CIP-313022.75	25.86	12	-0.36	1.18	1.80	3	15	4	4
CIP-396009.239	27.73	11	-2.71	-0.38	10.27	13	24	11	11
CIP-313033.06	47.80	1	1.33	-0.70	5.10	7	8	2	2
CIP-395037.12	25.81	13	1.10	2.62	4.93	6	19	8	8
CIP-313022.117	30.80	7	0.76	0.04	2.89	4	11	3	3
CIP-313024.211	24.63	14	1.46	1.53	5.74	9	23	10	10
CIP-395126.6	41.98	2	-0.39	-0.65	1.63	2	4	1	1
CIP-313022.07	29.85	10	2.32	-3.05	9.29	11	21	9	9
CIP-313022.118	31.08	6	0.94	0.55	3.59	5	11	3	3
CIP-308538.213	31.40	5	-3.60	0.29	13.63	14	19	8	8
CIP-313039.127	30.56	9	-1.37	0.28	5.20	8	17	6	6
CIP-313037.312	33.40	3	0.14	-1.02	1.15	1	4	1	1
Jalene	31.68	4	2.56	0.32	9.71	12	16	5	5
Gudane	30.77	8	-2.19	-1.01	8.36	10	18	7	7

Figure.1 AMMI 2 biplot for IPCA 1 against IPCA 2 scores for 14 genotypes and seven environments

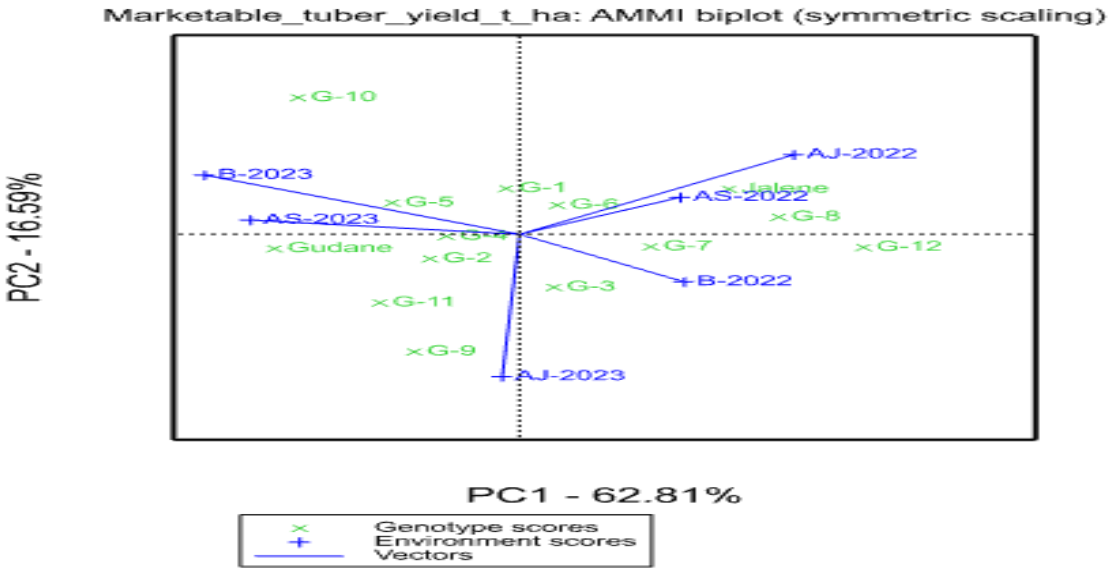


Figure.2 The GGE-biplot for "which -won -where" pattern for genotypes and environments

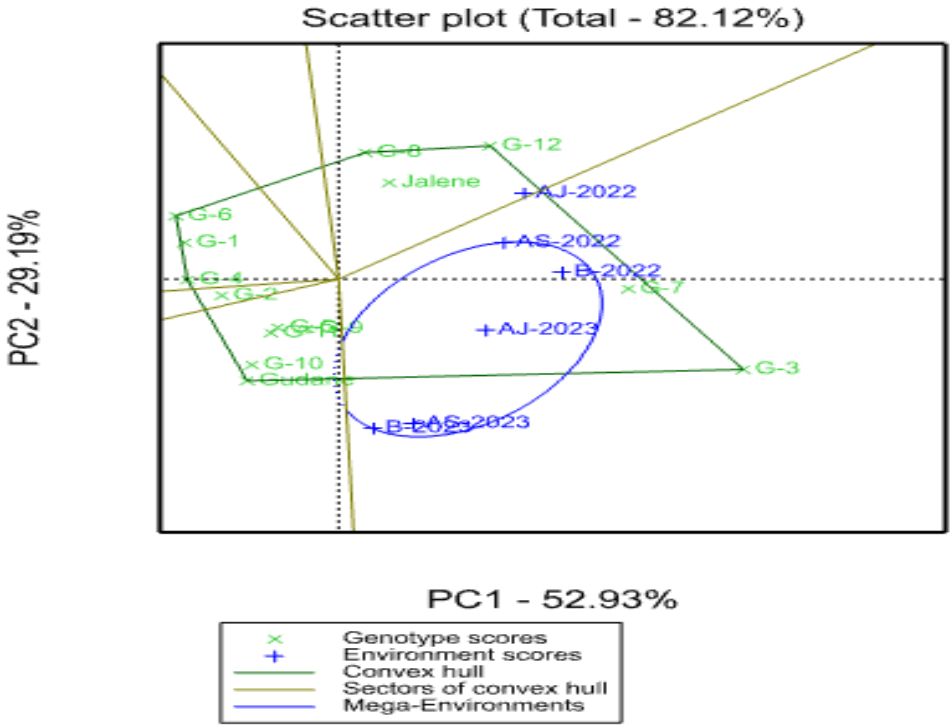


Figure.3 GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability.

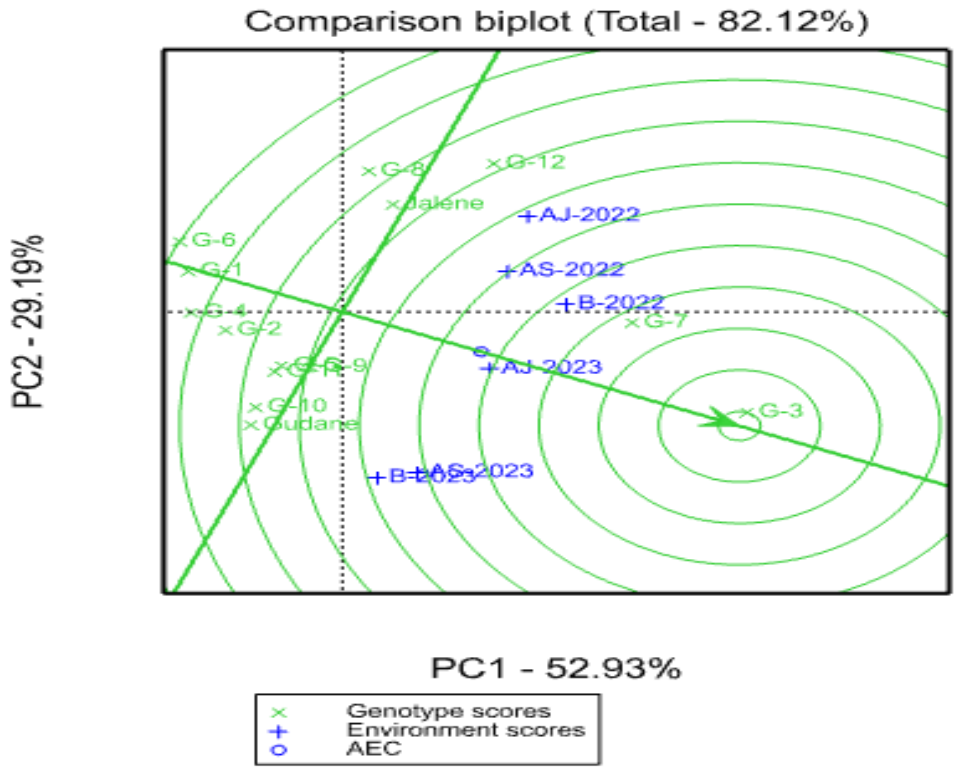


Figure.4 GGE ranking bi-plot shows means performance and stability of 14 genotypes.

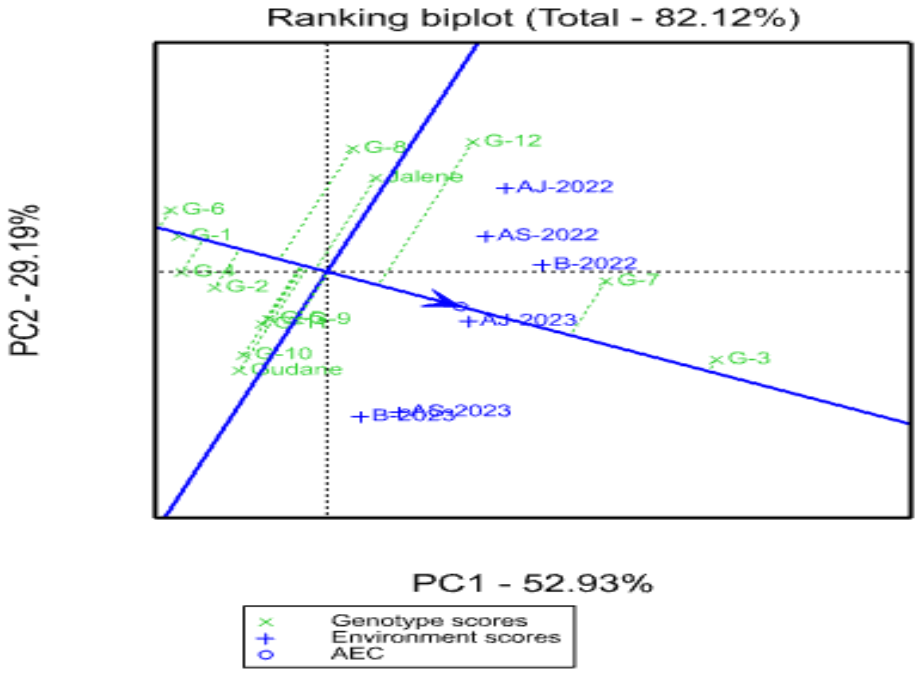
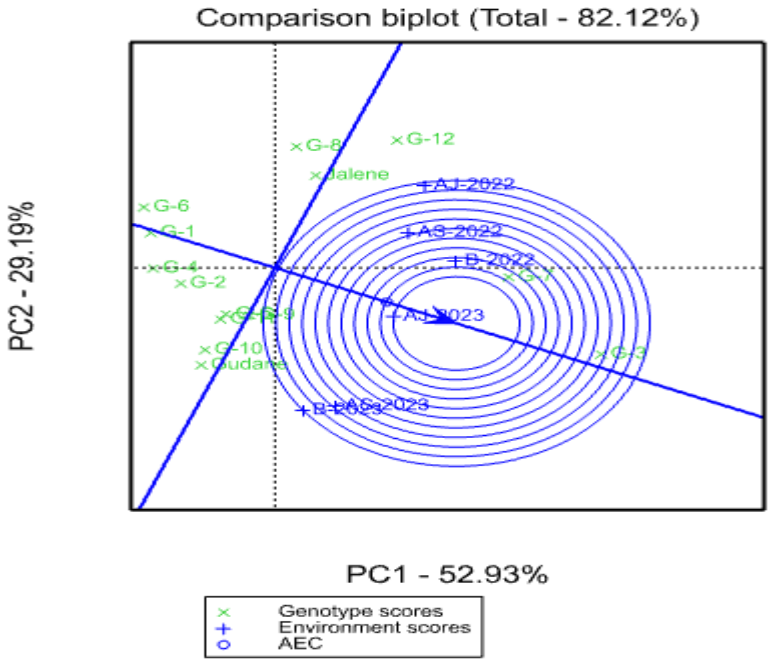


Figure.5 GGE bi-plot based on environment-focused scaling for comparison of all environments with the ideal environment.



Genotypes or environments which appear almost on a perpendicular line have similar means; those falling on horizontal line have similar interaction effects (Zobel *et al.,* 1988). G-10(CIP-308538.213), G-9(CIP-313022.118), G-211(CIP-313024.211), and G-07(CIP-313022.07) are placed furthest from the point of origin, showing specific adaptation to the environments within their proximity on the bi-plot. Moreover, G-7(CIP-395126.6), G-12(CIP-313037.312), G-3(CIP-313033.06), and Jalene had above-average yields and were located on the acute angle of PC1. Genotypes located on the right-hand side of the bi-plot were positively correlated with the environments on the same side. AJ-2023, AS-2022 and B-2022 locations were considered highly discriminating and had similar discriminating ability of the site since they had longer vectors.

GGE Biplot Stability Analysis

GGE biplot was the best way to visualize the interaction patterns between genotypes and environments to effectively interpret a biplot (Yan and Kang, 2003). In this study, the 'which won where' feature of the biplot identified the winning genotypes. The application of the biplot for partitioning through GGE biplot analysis showed that PC1 and PC2 accounted for 52.93% and 29.19% of GGE sum of squares, respectively (Figure 2).

Mega-Environments Analysis

The polygon view of a GGE biplot clearly displays which won-where pattern, and hence it arranged the genotypes in such a way that some of them were on the vertices while the rest were inside the polygon.

The genotype located at the vertex of the sector was considered the best-performing genotype in the Mega Environments (MGE).G-3(CIP-313033.06), G-7 (CIP-395126.6), and G-12 (CIP-313037.312) were the vertex (winning genotypes) in the sector where environments located in the MGE sector. Another interesting feature of the GGE biplot is the identification of mega-environments.

In genotype focusing scaled comparison of GGE biplot, a genotype located nearest to the central concentric circles is both high marketable tuber yielding and most stable. The GGE bi-plot analysis for marketable tuber yield of Potato genotypes based on genotype focused scaling comparison is presented in Figure 3. An ideal genotype is defined as the genotype having the greatest PC1 score (high mean performance) and with zero G x E interaction, as represented by an arrow pointing to it (Figure 3). Figure 3 depicts that genotype G-12 (CIP-313037.312), G-3(CIP-313033.06), and G-7(CIP-395126.6) which fell in the first concentric circle, were

the ideal genotypes in terms of higher yielding ability and stable. Ideal test environment, which is the center of the concentric circles has more power to discriminate genotypes in terms of the genotypic main effect as well as able to represent the overall environments. Among the testing environments (AJ-2023, AS-2023 and B-2022) were highly to discriminate genotypes as well as the representative testing site Yan (2001) reported that ideal" test environment, which is a virtual environment that has the longest vector of all test environments (most discriminating) and it is located on the AE (most representative environment).

Genotype Yield and Stability Performance

The Average-Environment Axis (AEA) or Average-Tester-Axis (ATA) is the line that passes through the average environment and the biplot origin (Yan and Kang, 2002). The average environment coordinates (AEC X-axis) or the performance line passes through the biplot origin with an arrow indicating the positive end of the axis (Figure 4). The AEC Y-axis or the stability axis passes through the plot origin with double arrow head and is perpendicular to the AEC X-axis. The mean performance and stability of these 14 genotypes in 6 locations showed genotypes G-3(CIP-313033.06), and G-7(CIP-395126.6) were high yielding and stable genotype. An ideal genotype should have both high mean yield performance and high stability across environments (Kaya *et al.,* 2006; Yan and Tinker, 2006).

Environment Discriminating Ability and Representativeness

The positive correlation existing between the genotypes and environments indicated that these genotypes possessed a specific adaptation. This provides little or no information about the genotype differences, since the genotypes show broad adaptability. Ideal test environment, which is the center of the concentric circles has more power to discriminate genotypes in terms of the genotypic main effect as well as able to represent the overall environments.Among the testing environments (AJ-2023, AS-2023 and B-2022) was highly to discriminate genotypes as well as the representative testing site. Ideal test environment should be highly discriminative of the genotypes and representative of the mega-environment (Yan *et al.,* 2007). Yan (2001) also reported that ideal" test environment, which is a virtual environment that has the longest vector of all test environments (most discriminating) and it is located on the AE (most representative environment).

Conclusion and Recommendation

Genotype by environment interaction and stability measuring trials helps to identify genotypes with both high performance and high stability. The study concluded the existence of a considerable degree of genotype by environment interaction for marketable tuber yield stability in Potato genotypes when evaluated in mid to highland areas of Guji zone. The G × E analysis enables identification of genotypes with narrow adaptation, which can significantly improve crop productivity in specific regions. Stable, high yielding and resistant reaction to late blight genotypes were identified and selected based on their relative response to respective locations.

As a result, two genotypes showed 50.88% and 32.50% marketable tuber yield advantage over the standard check, resistant reaction to late blight, showed stable performances, having acceptable dry matter content, specific gravity and starch content, and other desirable agronomic characteristics. Taking into account simultaneously, marketable tuber yield, internal quality, resistant reaction to late blight, and stability, genotypes G-3(CIP-313033.06), and G-7(CIP-395126.6) were selected as the high yielding and suggesting their adaptation to a wide range of environments and recommended to be included in variety verification trial for eventual varietal release to the set of tested environments and similar agro-ecologies in the country.

Acknowledgement

I would like to acknowledge Oromia Agricultural research Institute particularly Bore Agricultural research center for funding and provision of facilities to conduct the trials. I am also acknowledging all team members of Bore horticulture and spice team for their active participation on field work. Lastly, I acknowledge Bore drivers, and Tekalign Afeta who were involved in the seed collection, field work and technical assistance during data analysis.

References

Abebe Chindi.2019, Review of Potato Research and Development in Ethiopia: Achievements and Future Prospects. Journal of Biology, Agriculture and Healthcare ISSN 2224-3208 (Paper) ISSN 2225-093.

Adane H., Meuwissen M.P.M., Agajie Tesfaye A., Lommen W.J.M., Lansink A.O., Tsegaye A.,

Struik P.C.2010, Analysis of seed potato systems in Ethiopia. Amer. J. Potato Res., 87, 537-552

Anonymous.2004, Directory of released crop varieties and their recommended cultural practices. Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia.

Arega Amdie, Nigussie Dechassa, and Wassu Mohammed.2020,Response of Potato (*Solanum tuberosum* L.) to Blended NPS and Potassium fertilizers at Bore, Southern Ethiopia, *International Journal of Agriculture and Biosciences*; P.232-245.

Berga, L., Gebremedhin, W., Teriessa, J. and Bereke, T. 1994, Potato Agronomy Research. *In*: Herath and Lemma, Eds., *Horticulture Research and Development in Ethiopia*, *Proceedings of the* 2*nd National Horticultural Workshop of Ethiopia*, Institute of Agricultural Research, Addis Ababa, 2-5 February 1992, 182-196.

Bezabih Emana and Mengistu Nigussie. 2011, Potato Value Chain Analysis and Development in Ethiopia Case of Tigray and SNNP Regions. Report submitted to International Potato Center (CIP-Ethiopia),c/o ILRI, P.O. Box 5689, Addis Ababa Ethiopia

Ceccarelli, S. 1989, Wide adaptation.Euphytica 40, 197-205

CIP (International potato center). 2018, Potato Facts and Figures: http://cipotato.org/potato/facts.

CIP (International Potato Center). 2006, Procedures for standard evaluation trials of advanced potato clones. An International Cooperators' Guide.

CSA (Central Statistical Agency).2022, Report on Area and Production of Major Crops.Agricultural sample survey Addis Ababa Statistical Bulletin V.(1) pp: 143,10-111.

Dembi Korji and Basha Kebede. 2017,On farm demonstration of adapted Potato (*Solanum tuberosum L.*) in Highlands of Guji zone, Oromia Region, Ethiopia. *Academic Research. Journal Agriculture Science*, Vol. 5(7), pp. 514-520.

Devaux, A., Kromann, P., and Ortiz, O.2014, Potatoes for sustainable global foodsecurity. *Potato Res.* 57, 185–199. doi: 10.1007/s11540-014-9265-1

FAO (Food and Agriculture Organization). 2000, Fertilizers and their use; 4th edit: Food and Agriculture Organization of the United Nations International Fertilizer Industry Association, Rome, Italy.

FAO (Food and Agriculture Organization). 2018, Potato World: Production and Consumption.

FAO (Food and Agriculture Organization).2009, International year of the potato 2008: new light on a hidden treasure. http://www.fao. org/potato-2008/en/events/book.html

Gebremedhin,W., Endale, G., and Kiflu, B. 2001,National potato research program report. Ethiopian Agricultural Research Organization, Holetta Agricultural Research Center.

Gomez, K. A., and Gomez, A A. 1984, Statistical Procedures for Agricultural Research, 2nd edition, John Wiley and Sons, New York, p.680.

Gusha, S. 2014, From Potato Fields to Potato Sacks. Pastorial Response.Anglical Diocese of Harare, Zimbabwe.

Henfling, J.W. 1987, Late blight of potato: *Phytophthorc infestans*. Technical Information BL Iletin 4. International Potato Center, Lirma, Peru. 25 pp. (Second edition, revised).

Humans R.J., Condori, B., Carillo, R.and Kropff, MJ. 2003. A quantitative and constraint-specific method to assess the potential impact of new agricultural technology: the case of frost resistant potato for the Altiplano (Peru and Bolivia). Agr Syst. 76: 8gLgll.

Kaya yukselAkçuramevlut and Taner seyfi. 2006, GGE-biplot analysis of multi-environment yield trials in bread wheat. *Turkish Journal of Agriculture and Forestry*, *30*(5)325-337.

Kleinkopf, G.E., Westermann, D.T., Wille, M.J., Kleinscmidt, G.D. 1987, Specific Gravity of Russet Burbank Potatoes. Am. Potato J. 64: 579-587.

Kumar, C.V., Prakash, S.S., Prashantha, G.M., Mahendra, K.M.B., Lohith, S. and Chikkaramappa, T. 2013, Dry matter production and yield of potato as influenced by different sources and time of fertilizer application and soil chemical properties under rainfed conditions. *Research Journal of Agricultural Sciences,* 4(2): 155-159.

Lemma, T., Wassu, M., Tesfaye, A. 2020, Evaluation of Potato (*Solanum tuberosum* L.) Varieties for Yield and Some Agronomic Traits. Open Agric.5:63–74. https://doi.org/10.1515/opag-2020-0006.

Martha and Ann.2017, Organic Potato Production on the California's Central Coast: A Guide for Beginning Specialty Crop Growers by Jim Leap, Darryl Wong, Orin Martin, and Kirstin Yogg-Comerchero, PP.1-12.

Menza, M., Gebrerufael Girmay, G., Gamo, F.W.2014,Enhancing household food security

through Potato production in Gamo Highlands of Southern Ethiopia, Sch. J. Agric. Sci. 4 (7) 410–419.

Mesifn,H. 2022, Adaptability and stability for soybean yield by AMMI and GGE models in Ethiopia. Front. Plant Sci. 13:950992. doi: 10.3389/fpls.2022.950992.

Nakitandwe,J.,Adipala, E., El-Bedewy, R., Wagoire, W., Lemaga, B., 2005,Adaptability of sift potato genotypes in different agro-ecologies of Uganda. *African Crop Science Journal* 13: 107–116.

Pandey, N.K., Dhiraj, K. and Kumar, R.S. 2014, Summer School on "Current Trends in Quality Potato Production, Processing and Marketing" (8th to 28th July, 2014). Central Potato Research Institute, Shimla, New Delhi.

Ruswandi, D., Anggia, E., Hastini, T., Suhada, A., Istifadah, N., Ismail, A., Suryadi, E., Ruswandi, S., Rostini, D. N.2008,Selection of DR Unpad field corn hybrids based on their yield stabilities and adaptabilities in eight location in Indonesia. – Zuriat 19(1): 71- 85.

Simmonds, N.W.1991, Selection for local adaptation in plant breeding programmes. Theoretical and Applied Genetics 82: 363-367.

Talburt,W.F., Smith,O.1959,Potato processing. The AVI. Publishing Company, Inc. Westport, 10.5962/bhl.title.69159

Tekalign Afeta,Bulti Tesso and Dagnachew Lule. 2019, Interaction Effects of Genotype by Environment and AMMI Stability Analysis of Seed Yield and Agronomic Performance of Faba Bean Genotypes in the Highlands of Oromia Region, Ethiopia, International Journal of Research in Agriculture and Forestry, Volume 6, Issue 10, 2019, PP 22-31.

Wassu, M. 2006, Specific Gravity, Dry Matter Content, and Starch Content of Potato (*Solanum tuberosum* L.) Varieties Cultivated in Eastern Ethiopia. *East African Journal of Sciences*. ;10(2):87–102.

William, M. A., Woodbury,G.W.1968,Specific gravity dry matter relationship and reducing sugar changes affected by potato variety, production area and storage. American Journal of Potato 45(4):119-131.

Yan W, MS Kang, MAS Woods, and PL Cornelius. 2007, GGE Bi-plot Vs. AMMI Analysis of Genotype-by environment data. Crop Sci., 47: 643-655

Yan, W.,and Kang, M..S. 2003, GGE Biplot Analysis: A Graphical Tool for Breeders, Geneticists, and Agronomists. CRC Press. Boca Raton, FL, USA.

Yan, W. and Tinker, N.A. 2006, Biplot analysis of multi-environment trial data: Principles and applications. *Canadian journal of plant science*, *86*(3): 623-645.

Yan,W. 2001, GGEBiplot – a Windows application for graphical analysis of multi-environment trial data and other types of twoway data. Agron. J. 93: 1111–1118.

Yan,W. 2002, Singular value partitioning for biplot analysis of multi-environment trial data. Agron. J. 94: 990–996.

Zaheer, K., and Akhtar, M. H. 2016, Potato production, usage, and nutrition–a review. Crit. Rev. Food Sci. Nutr. 56, 711–721. doi: 10.1080/10408398.2012.724479.

Zavala-Garcia, F., Bramel-Cox, P. J., and Eastin, J. D. 1992, Potential gain from selection for yield stability in two grain sorghum populations. Theoretical QlJd Applied Genetics 85 ; 112--9.

Zobel, R. W., M. J. Wright, and H. G. Gauch Jr, 1988, Statistical analysis of a yield trial. Agronomy journal, 80 (3): p. 388-393.

How to cite this article:

Arega Amdie, Solomon Teshoma and Miressa Mitiku. 2025. Genotype by Environment Interaction and Stability Analysis of Marketable Tuber Yield of Potato (*Solanum tuberosum* L.) Genotypes in Guji Zone, Southern Oromia, Ethiopia. *Int.J.Curr.Res.Aca.Rev.* 13(05), 47-60. doi: https://doi.org/10.20546/ijcrar.2025.1305.007