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Genotype and Environment Interaction and Marketable Tuber Yield Stability of Potato (*Solanumtuberosum L*) Genotypes Grown in Bale Highlands, Southeastern Ethiopia

Fufa Miheretu*

Sinana Agricultural Research Center, Horticulture division, Ethiopia

Abstract

Twelve potato (*Solanumtuberosum L.*) genotypes were evaluated using randomized complete block design (RCBD) with three replications to evaluate their genotype x environment interaction (GEI) and marketable tuber yield stability across nine environments during 2009-2011 at highlands of Bale, Southeastern Ethiopia. The combined analysis of variance (ANOVA) revealed that there was significant ($p<0.05$) variation in genotype x environment interaction in marketable tuber yield. Genotype, environment and genotype x environment interaction respectively explained 18.86%, 51.88% and 29.26% of the total sum of squares in marketable tuber yield (t/ha).Most of the total sum of squares in marketable tuber yield is contributed by environment. The AMMI analysis for marketable tuber yield (t/ha) indicated that IPCA1, IPCA2 and IPCA3 were highly significant ($p<0.01$) while IPCA4 showed non-significant interaction. The first and second principal component axis captured 40.37% and 30.8% of the GEI sum of squares in marketable tuber yield. Genotype 394640-539 gave high mean marketable tuber yield that is the most stable across environments. It was, thus, selected and recommended for wide production across locations.

Key words: AMMI stability; GEI; Potato (*Solanumtuberosum L.*)

Introduction

Potato (*Solanumtuberosum L.*), belonging to the family Solanaceae, is an important food and cash crop ranking fourth after maize, wheat and rice in annual production in the world [1,2]. It is the world's number one none-grain crop to ensure food security due to its growing demand [3]. It is a high biological value crop that gives an exceptionally high yield with more nutritious content per unit area per unit time than any other major crops. Thus, it can play a remarkable role in human diet as a supplement to other food crops such as wheat and rice [4]. Furthermore, the contribution of potato to the diversification of the cereal mono-cropping in Bale is great.

Despite the importance of potato in the country agriculture, its productivity has shown a decreasing trend even if its production is expanding steadily [5,6].One of the major factors contributing to reduction in yield of potato is inadequacy of improved cultivars with wide adaptability and stability in tuber yield. Thus, evaluating genotypes across various environments for their stability of performance and range of adaptation is crucial and is an important component of the research activity of the national as well as regional research program.

Evaluating genotypes over diverse environments is universal practice to ensure the stability of performance of the genotypes [7]. Stability in performance is one of the most desirable properties of a genotype to be released as a variety for wide cultivation [8]. However, the activity of identification, selection and recommendation of superior genotypes is complicated and severely limited by genotype × environment interaction that is inevitable in multi-environmental trails [9-13]. The presence of genotype x environment interaction may confound the genotypic performance with environmental effects [14].

Several statistical models and procedures have been developed and exploited for studying the genotype x environment interaction effects, stability of genotypes and their relationships in varietal development process [9-11,15]. A combined analysis of variance (ANOVA) can quantify the interactions and describe the main effects. However, it is uninformative for explaining genotype x environment interaction. To increase accuracy, additive main effects and multiplicative interaction (AMMI) is the model of first choice when main effects and interaction are both important [13]. It is a powerful tool for effective analysis and interpretation of multi-environment data structure in breeding programs and is useful for understanding genotype x environment interaction [7,9]. Plant breeders frequently apply AMMI model for explaining genotype x environment interaction and analyzing the performance of genotypes and test environments [16,17]. Therefore, this paper assesses genotype x environment interaction and marketable tuber yield stability of potato genotypes under Bale highlands, Southeastern Ethiopia.

Materials and Methods

Twelve genotypes of potato were evaluated for their adaptability and stability in marketable tuber yield across locations in Bale highlands at Sinana, Shallo and Dinsho during 2009, 2010 and 2011. Sinana is located at an altitude of 2400 m.a.s.l. with a range of mean annual rainfall of 563-1018 millimeter and minimum and maximum temperature of 7.9 0C and 24.30C, respectively. The soil type is dark-brown with slightly acidic reaction [18].

The experiment was laid out in randomized complete block design with three replications. The genotypes were planted on a plot area of 9m2with spacing of 75 cm and 30cm between rows and plants respectively. All agronomic and cultural practices were followed as per the general recommendation: the fertilizer rate of 90Kg/ha P2O5 and 110 Kg/ha N was used without fungicide application. At physiological maturity, the tubers were harvested from two middle rows and washed with clean tap water to remove soils. The clean tubers were sorted and graded into large, medium and small based on their size. The weight of

***Corresponding author:** Fufa Miheretu, Sinana Agricultural Research Center, Horticulture division, Ethiopia Tel: +251 116 187 346; E-mail: miheretufufag@gmail.com

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the tubers per plot (kg) was recorded and their mean was subjected to analysis.

Statistical Analysis

Analysis of variance (ANOVA) was carried out on marketable tuber mean (t/ha) on plot basis and pooled over locations and seasons using the Generalized Linear Model (GLM) procedures of the Statistical Analysis System version, 9.2 [19]. The Additive Main Effects and Multiplicative Interactions (AMMI) statistical model and biplot were produced using Irristat software [20].Furthermore, AMMI's stability value (ASV) was calculated in order to rank genotypes in terms of stability using the formula suggested by Purchase [21] as shown below:

$$\text{AMMI stability value (ASV)}=\sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1score)\right]^2+\left[IPCAscore2\right]^2}$$

where, SS = Sum of squares; IPCA1 = interaction principal component analysis axis 1and IPCA2 = interaction principal component analysis axis 2. Genotype by environment interaction

Results and Discussion

The combined analysis of variance indicated that there is significant variation ($p<0.05$)in genotype x environment interaction for marketable tuber yield (t/ha) (Table 1). The significant variation in genotype x environment interaction indicate that there is a need to undertake additive main effects and multiplicative interaction(AMMI) analysis to distinguish which genotypes are stable in their marketable tuber yield. The analysis of variance for additive main effect and multiplicative interaction model of marketable tuber yield (t/ha) of the 12 potato genotypes was indicated in Table 2.

Genotypes, environment and genotype x environment interaction respectively explained 18.86%, 51.88% and 29.26%of the total sum of squares in marketable tuber yield (t/ha). Most of the total sum of squares are contributed by environment indicating that environment is diverse, with large difference among the environmental means causing most of the variation in marketable tuber yield (t/ha). The magnitude of genotype x environment interaction sum of squares was 1.551 times larger than that of genotypes in marketable tuber yield, implying that there was difference among genotypic response across environments (Table 1).This variability may be due to the variability of soil and rainfall across locations. AMMI stability analysis of marketable tuber yield

Source	DF	Mean Square
GEN	11	738.09687***
LOC	2	8953.56433***
Year	2	1347.07762***
REP (LOC*Year)	18	68.25173ns
GEN*LOC	22	135.37407***
GEN_*Year	22	255.59237***
LOC*Year	4	432.03913***
GEN*LOC*Year	44	90.71289**
Error	198	61.32870
CV	34.77	
R2	0.79	

Ns, ** and ***= non-significant, significant and highly significant at 0.05 and 0.01 level of significance respectively.

Table 1. Mean squares of combined analysis of variance of marketable tuber yield (t/ha) of 12 genotypes evaluated across location (2009-2011)

The AMMI analysis for marketable tuber yield (t/ha) indicated that IPCA 1, IPCA2 and IPCA3 were highly significant ($p<0.01$) while IPCA 4 showed non-significant variation (Table 2). The first principal component axis captured 40.37 % of the interaction sum of squares while second principal component axis explained 30.80% of the GEI sum of squares. IPCA 1 and IPCA 2 together had greater contribution (71.17%) to the total sum of squares than that of genotypes.

The mean and AMMI stability values of marketable tuber yield were indicated in Table 3. The highest (28.42t/ha) and the lowest (9.94t/ha) mean marketable tuber yield were recorded by genotype 387967-3 and the local cultivar respectively. Genotypes 387967-3, 394640-539, 90147-41, Jalane, Ararsa, 90170-37, 390012-2 and Hunde gave mean marketable tuber yield higher than the grand mean. On the other hand, 90147-15, 392637-500, 90147-46 and local gave mean yield lower than the grand mean. The most stable genotype in marketable tuber yield was 394640-539 based on AMMI stability value while the local, 90147-41 and Jalane are the most unstable genotypes. Based on the AMMI stability value, genotype 394640-539 was selected for wide production as it gave high mean marketable tuber yield that is stable across environments.

AMMI biplot analysis of marketable tuber yield

Both genotypes and environments differed in their interaction as well as main effects for marketable tuber yield (Figure 1). Genotype3 (Local) was the lowest in its mean marketable tuber yield while genotype 5 (387967-3) and 2 (394640-539) were higher in their marketable tuber yield. Environment E and B were highly productive while environment D was poor in marketable tuber yield. Genotypes 3 (Local), 6 (90147-46), 10 (90170-37), 2 (394640-539) and 5 (387967-3) showed positive interaction with environment B, D, E and F. On the other hand, genotypes 4 (392637-500), 7 (90147-15), 1 (Hunde), 8 (390012-2), 9 (Ararsa), 11(Jalane) and 12 (90147-41)showed negative interaction with environment G, C, A and H. Genotype 3 (Local) was found adaptable to poor environment (D). On the other hand, genotypes 5 and 2 were found suitable to productive environments.

Figure 2 indicates the interaction pattern of the 12 potato genotypes with 9 environments for their marketable tuber yield (kg/

Source of variation	D.F	S.S	M.S	F	% explained
Genotypes	11	2706.36	246.032		18.86
Environments	8	7443.15	930.393		51.88
Genotypes X environments	88	4197.54	47.6994		29.26
AMMI COMPONENT 1	18	1694.65	94.1471	2.633***	40.37
AMMI COMPONENT 2	16	1292.99	80.8117	3.607***	30.80
AMMI COMPONENT 3	14	575.534	41.1096	2.592***	13.71
AMMI COMPONENT 4	12	224.574	18.7145	1.279ns	5.35
GXE RESIDUAL	28	409.800			
TOTAL	107				

Ns, ** and *** = non-significant, significant and highly significant at 0.05 and 0.01 level of significance respectively.

Table 2 Analysis of variance for Additive Main effect and Multiplicative Interaction (AMMI) model of marketable tuber yield of potato genotypes grown at highlands of Bale, South eastern Ethiopia (2009-2011)

Genotype	Mean	AMMI1	AMMI2	ASV	R
387967-3	28.42	4.535***	1.382 ***	1.905	6
394640-539	28.10	0.5389***	0.5713***	0.908	1
90147-41	26.29	-2.652***	0.7525	3.556	11
Jalane	25.87	-1.490***	2.961	3.547	10
Ararsa	24.82	-1.158***	0.8290	1.729	4
90170-37	23.77	1.674	0.8806	2.364	6
390012-2	23.19	-1.372***	-0.9574***	1.798	5
Hunde	25.72	-0.8035***	1.154***	1.562	2
90147-15	20.34	-1.102	-2.435 ***	2.831	9
392637-500	20.26	-0.3904	1.583	1.665	3
90147-46	16.69	0.5864	-2.256	2.383	8
Local	9.94	1.634***	-2.899	3.604	12
Mean	21.11				

ASV= AMMI stability value

Table 3: Mean and AMMI stabilityof marketable tubers of 12 genotypes evaluated over locations (2009-2011)

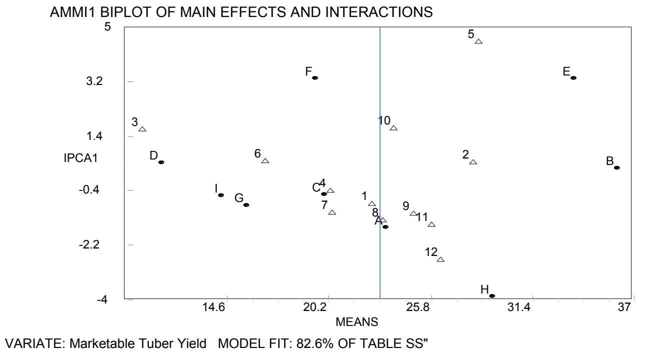

Figure 1 AMMI 1 biplot of 12 potato genotypes evaluated in 9 environments for marketable tubers (Kg/ha) of Bale, Southeast Ethiopia

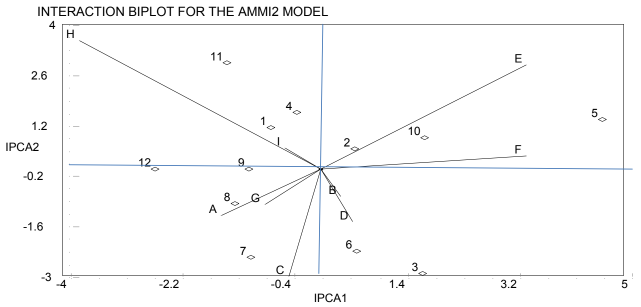

Figure 2: AMMI biplot of 12 genotypes of potato evaluated across locations for their marketable tubers
NB: Genotypes: 1=Hunde, 2=394640-539 3=Local, 4=392637-500, 5=387967-3, 6= 90147-46, 7= 90147-15, 8= 390012-2, 9= Ararsa, 10=90170-37, 11= Jalane and 12= 90147-41.
Environments: A=Sinana 2009, B=Shallo2009, C= Dinsho 2009, D=Sinana 2010, E= Shallo 2010, F= Dinsho 2010, G= Sinana 2011, H= Shallo2011 and I=Dinsho 2011.

ha). The distance from the origin (0,0) is indicative of the amount of interaction that was exhibited by genotypes either over environments or environments over genotypes [22].The genotypes 5(387967-3), 11 (Jalane), 3 (Local), 12 (90147-41), 7 (90147-15) and 6 (90147-46) expressed a highly interactive behavior (positively or negatively) while genotype 2 (394640-539) show low interaction and thus stable in its marketable tuber yield (Kg/ha) (Figure 2). The environments H, E and F were highly interactive while B, I and D showed low interaction.

Conclusion

The combined analysis of variance of marketable tuber yield (t/ha) indicated that there was significant ($p<0.05$) genotype x environment interaction. Most of the total sum of squares in marketable tuber yield was explained by environment than genotype. The Local cultivar was found adaptable to poor environment while genotypes 394640-539 and387967-3were found suitable to productive environments. Genotype 394640-539 was selected for wide production for it had stable and high mean marketable tuber yield across the environments.

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