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Phenotypic stability for tuber yield in élite potato (*Solanum tuberosum* L.) genotypes in eastern Ethiopia

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An experiment was conducted during the 1998 and 1999 cropping seasons at six different locations in eastern Ethiopia to study the phenotypic stability of nine medium-maturing élite potato (*Solanum tuberosum* L.) genotypes and to understand the nature and magnitude of genotype by environment (G × E) interaction in potato. At all locations, the experimental plots were arranged in a randomized complete block design with three replications. Significant differences among genotypes were observed and the G × E interaction was also significant. Both linear and non-linear components of G × E interactions were found to be important with a predominance of the former. The CIP-389668-4 clone exhibited above average responsiveness along with stability, indicating that it had specific adaptability for favourable environments. The next highest-yielding clone was CIP-388764-26 with stable average responsiveness, indicating that it had general adaptability. The third highest-yielding genotype (CIP-387412-2) was unstable. Similarly, Chiro, the widely grown potato genotype (control) was found to be unstable. Clone CIP-388764-26 is recommended for regional release.

Keywords: Potato; Stability; Phenotype; Environment; G × E Interaction; Tuber yield; Eastern Ethiopia

The cultivated potato (*Solanum tuberosum* L.) varieties are well adapted to cool temperate zones (Hawkes, 1978). However, through the development of adaptive cultivars, potato cultivation has been introduced on a large scale to tropical and subtropical areas. Most of the potato cultivars bred for temperate climate respond to the tropical and subtropical growing conditions with a significant loss of tuber yield and quality (Levy, 1983, 1984). An understanding of genotype by environment (G × E) interaction is an important component of plant breeding to enhance the productivity of potato in high-temperature-prone regions (Jackson *et al.*, 1996; Yan and Hunt, 1998). Furthermore, identifying the causes of G × E is of paramount importance in establishing breeding objectives, selecting ideal test conditions, and formulating recommendations for an adaptive cultivar in a specific area. The existence of G × E in potato has been previously reported by various researchers (Sekioka and Lauer, 1970; Tai, 1971, 1979; Tai and Young, 1972; DeJong *et al.*, 1981; Yildirim and Caliskan, 1985; Tai *et al.*, 1994; Baril *et al.*, 1995).

Ethiopia is known to have suitable edaphic and climatic conditions favourable for high quality potato production. About 70% of the available agricultural land is situated at an altitude range of 1800–2500 m above sea level with annual rainfall of 600 mm, which is conducive for high quality ware and seed potato production. However, the national average tuber yield (8.33 t ha^{-1}) is very low compared to the world's average yield of 16.02 t ha^{-1} (FAO, 1999). A lack of well-adapted potato cultivars to the different agro-ecological zones of the country is the most crucial factor accounting for this low yield. To overcome this problem, the Potato Improvement Program of the Alemaya University was established with the major objective of developing widely-adaptable, high-yielding, stable potato varieties with good resistance to biotic and abiotic stresses. To achieve this, the programme has been introducing potato germplasm having a wide genetic base from International Potato Centre (CIP) and testing them across locations. Therefore, the aim of the present investigation was to study the phenotypic stability of nine élite potato genotypes in eastern Ethiopia to identify potato varieties with high yield combined with adaptability and also to understand the nature and magnitude of G × E interactions in potato.

Materials and Methods

Nine medium-maturing potato clones, viz., CIP-388764-26, CIP-387412-2, CIP-387096-11, CIP-381381-20, CIP-389668-4, CIP-386029-18, AL-269, AL-105, and Chiro (control) were evaluated at Alemaya, Arberekete, Asebe Teferi, Dire Teyera, Kerssa, and Hirna, during the 1998 and 1999 cropping seasons under rainfed conditions. The locations are diverse in

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climate and soil type and are used as testing sites for the potato improvement programme of Alemaya University and they represent the major potato-growing areas of eastern Ethiopia. The location of mean temperature, rainfall, and soil textural class of the experimental sites are provided in Table 1.

At all locations, the experimental plots were arranged in a randomized complete block design with three replications. Forty medium-sized well-sprouted tubers of each clone were planted in four rows at inter-row and intra-row spacings of 75 cm and 30 cm, respectively. Rows were set in a continuous arrangement, while the end rows were bordered by two rows of potato plants. Phosphorus was applied as diamonnium phosphate at planting time at the rate of 300 kg ha^{-1} and N as urea was side-dressed after full emergence at the rate of 200 kg ha^{-1}. All cultural practices were employed as per the recommendation of Teriessa (1995). After maturity, the central rows were harvested and tuber yield were recorded in kilograms and finally converted into tonnes per hectare.

The Bartlett (Bartlett, 1937) test of homogeneity of variance was applied and the data were subjected to combined analysis of variance to obtain estimates of environmental, genotypic, and G × E interaction sources of variation. Computation of stability parameters for each genotype and partitioning of G × E interaction into linear and non-linear components were done using the procedure developed by Eberhart and Russell (1966). The following linear model developed by Eberhart and Russell (1966) was used.

$$Y_{ij} = \mu_i + b_i I_j + \delta_{ij}$$

where, Y_{ij} = Mean performance of ith variety in jth environment

μ_i = Mean of the ith variety over all the environments

b_i = Regression coefficient

I_j = Environmental index

δ_{ij} = Deviation from regression of the ith variety at jth environment

The regression coefficient (b_i) and the mean square deviation (S^2d_i) were used as measures of yield responsiveness and stability, respectively (Eberhart and Russell, 1966). The analysis of variance and the linear regression were performed using STATISTICA computer software (STATSOFT, 1999).

Results and Discussion

The Barlett (Bartlett, 1937) test of homogeneity indicated that the observed χ^2 was less than the tabular value ($P < 0.01$), and the error variances of 12 environments (Table 2) were homogeneous. Hence, a pooled analysis was done.

There were significant differences among genotypes for tuber yield (Table 3), which agrees with earlier studies on potato by Tai and Young (1972) and DeJong *et al.* (1981). The G × E interaction was also significant. Similar investigations on potato indicated the existence of G × E interactions for tuber yield

Table 1 Location, mean temperature, rainfall, and soil textural class of the testing sites used in this study

Site	Longitude	Latitude	Altitude	Annual mean temp.	Annual mean RF[1]	Soil texture
Alemaya	42°03′ E	9°24′ N	1980 m	16.9°C	843 mm	Sandy loam
Arberekete	41°06′ E	8°94′ N	2240 m	18.5°C	890 mm	Sandy clay loam
Asebe Teferi	40°98′ E	8°94′ N	1900 m	19.0°C	750 mm	Silty clay loam
Dire Teyera	42°08′ E	9°22′ N	2050 m	17.6°C	850 mm	Sandy loam
Kerssa	41°67′ E	9°31′ N	1940 m	17.8°C	835 mm	Silty clay
Hirna	41°06′ E	9°19′ N	1960 m	19.5°C	863 mm	Clay

[1]Rainfall

Table 2 Analysis of variance of tuber yield (t ha^{-1}) of potato genotypes tested at six locations for two years

		Environments											
		1998						1999					
Source	df	E_1	E_2	E_3	E_4	E_5	E_6	E_1	E_2	E_3	E_4	E_5	E_6
Replication	2	73.93	14.73	145.35	163.94	11.98	14.32	41.55	26.24	77.28	11.95	22.87	73.72
Genotype	8	32.94	123.41	184.49	110.74	12.08	124.88	47.61	149.76	63.20	53.92	139.87	395.71
Error	16	18.63	37.03	24.92	50.90	10.17	36.74	15.34	40.07	37.35	7.294	29.68	24.08

χ^2, 13.24**, Highly significant at 1% level of significance
E_1, Alemaya; E_2, Arberekete; E_3, Asebe Teferi; E_4, Dire Teyera; E_5, Kerssa; and E_6, Hirna
df, Degrees of freedom

in potato (Sekioka and Lauer, 1970; Tai, 1971, 1979; Tai and Young, 1972; DeJong *et al.*, 1981; Yildirim and Caliskan, 1985; Tai *et al.*, 1994; Baril *et al.*, 1995).

Further partitioning of G × E interaction (Eberhart and Rusell, 1966) into its linear and non-linear components, revealed that both components of G × E interaction were important as G × E (heterogeneity due to regression) and pooled deviation were found to be significant (Table 3). The *F*-test of heterogeneity of regression against pooled deviation was also significant indicating the predominance of linear type of G × E interaction, although an appreciable amount of non-linear G × E was noticed. Hence, it would be possible to predict the yield performance of individual genotypes across the environments (Perkins and Jinks, 1968)

The estimates of b_i presented in Table 4 disclosed that except for genotypes CIP-389668-4 and AL-269, estimates of b_i of the other genotypes were not significantly ($P > 0.05$) different from unity, suggesting that seven of the genotypes had average response across the environments for tuber yield.

Table 3 Analysis of variance for stability of tuber yield (t ha^{-1}) in nine potato genotypes

Source	df	MS
Genotypes (G)	8	153.69** ++
Environment (E) + (G × E)	99	104.59** ++
Environment (linear)	1	7748.14** ++
G × E (linear)	8	325.80** ++
Pooled deviation	90	24.29** ++
Pooled error	192	9.43

**, ++, Highly significant ($P < 0.01$) difference when tested against pooled error and pooled deviation, respectively
df, Degrees of freedom
MS, Mean Squares

Table 4 Stability parameters for tuber yield (t ha^{-1}) of nine potato genotypes

Genotype	Mean tuber yield (t ha^{-1})	Regression coefficient (b_i)	Deviation from regression (S^2d_i)
CIP-388764-26	39.59 (2)	1.260	3.44
CIP-387412-2	39.17 (3)	1.160	41.11**
CIP-387096-11	35.36 (5)	1.070	26.28**
CIP-381381-20	36.44 (4)	1.130	5.58
CIP-389668-4	41.38 (1)	1.330++	-2.19
CIP-386029-18	30.86 (9)	0.874	11.87*
AL-269	32.73 (8)	0.800+	16.96**
AL-105	32.96 (7)	0.777	15.59**
Chiro (control)	34.04 (6)	1.130	15.09**
Grand Mean	35.84	1.00	
SE (±)	0.88	0.12	

*, **, Significantly and highly significantly different from zero at 5 and 1%, respectively
+, ++, Significantly and highly significantly different from unity at 5 and 1%, respectively
Values in parenthesis are ranks of genotypes
SE, Standard Error

Tuber yield of the tested genotypes ranged from 41.38 t ha^{-1} (CIP-389668-4) to 30.86 t ha^{-1} (CIP-386029-18) with mean tuber yield over all genotypes and environments of 35.84 t ha^{-1} (Table 4). Six out of the tested nine clones were found to be unstable (Table 4). An examination of the performance of the top high-yielding genotypes (Table 4) in relation to their response to growing environments (b_i) and stability parameter (S^2d_i), disclosed that CIP-389668-4 had the highest tuber yield and above average response to favourable environments with stability. Thus, this genotype was designated as having specific adaptability to favourable environments. The second top ranking genotype, CIP-388764-26, exhibited average responsiveness together with stability, thus it was identified as a genotype having general adaptability across the environments, and hence, can be recommended for wider adaptability. However, the third genotype, namely, CIP-387412-2, although it was high-yielding with average response, it was unstable. Similarly, the widely-grown genotype Chiro that was used as a control in the study, was found to be unstable.

From the current investigation, it was observed that G × E interaction had substantial contribution in the performance of potato genotypes grown under different growing environments. As the main objective of the programme was to seek stable genotypes having general adaptability, the clone CIP-388764-26 was identified as a potential candidate for regional release. In addition, in the future, the potato breeding programme should give special emphasis for G × E interaction while developing high-yielding and stable genotypes.

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