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ESTIMATION OF STABILITY PARAMETERS OF POTATO GENOTYPES UNDER DIFFERENT SOWING SEASONS

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ABSTRACT: This investigation was carried out in Vegetable Private Farm at Al-Salhyia, Fakous District, Sharkia Governorate, Egypt. Eight potato genotypes were evaluated for tuber yield and its components as well as tuber dry matter (%) under six varied environments which are the combination between three years 2013/2014, 2014/2015 and 2015/2016 and two sowing seasons *i.e.,* fall and summer. The combined analysis of variance showed highly significant differences between genotypes, environments as well as G×E for all studied traits except for aerial stem No./plant which was insignificant, Phenotypic stability parameters revealed that potato genotypes Horaizon and Spunta were highly adapted to favorable environment. These results reflected the importance of environmental factors on the performance of genotype. According to phenotypic stability, the best cultivars were Horaizon and Caruso in most traits. For genotypic stability parameters, most cultivars considered stable in different studied traits. Horaizon, Hermus, Spunta and Inova were the most desired and stable for additive main effects and multiplicative interaction methods stability value (ASV) and regression coeffient (R^2) in most traits. The ideal potato culturar was Carus for tuber number/plant, while Hermus was the ideal for average tuber weight, tuber yield/plant, tuber yield/fad., and tuber dry matter according to genotype + genotype x environment.

Key words: *Solanum tuberosum* L., potato, stability analysis, genotype x environment interaction, AMMI, joint regression analysis, tuber yield.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is grown all over the world in diverse environments. It takes a considerable rank of fourth important food crops after wheat, rice and maize **(Manrique and Hermann, 2000)**. In Egypt, potato production comes mostly from two plantations per grown seasons; *e.g.,* fall and summer sowings. Therefore, planting potato for tuber production in different sowing seasons and years is subjected to genotype by environment interaction (G×E), which is considered an important source of variation.

So that the term stability is sometimes used to characterize a genotype, which shows a relatively constant yield independent of changing environmental conditions. Many traits of potato have been shown to be sensitive to environmental changes as reported by previous studies on potato **(Tai, 1971; Yildirim and Caliskan, 1985)**. Phenotypic stability refers to fluctuations in the phenotypic expression, while the genotypic composition of the varieties or populations remains stable in tomato **(Ismail, 2003)**. On the basis, genotypes with a minimal variance for yield across different environments are considered stable **(Sabaghiaa *et al.*, 2006)**.

Phenotypic stability parameters revealed that potato genotypes Horiazon, Spunta and Hermus were highly adapted to favorable environments in most traits. Genotypic stability parameters showed that potato genotypes Horaizon, Hermus, Caruso and Inova were stable in different studied traits.

In plant breeding, genotypes evaluate in multi-environment trails to test their performance across environments and to select the best

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genotypes for specific environment.

Variance due to G × E is an important component of the variance in selection experiments. A cultivar grown in different environments will frequently show significant fluctuation in yield performance relative to other cultivars **(Asfour and Zayed, 2010; El-Sharkawy and Abd El-Aal, 2013)**.

Several statistical methods have been suggested to find out the stability of new cultivars. The joint regression analysis of phenotypic values (b_i and S^2d_i) was proposed by **Finlay and Wilkinson (1963)** and used by **Eberhart and Russell (1966 and 1969)**. The determination coefficient of regression (R^2) was calculated according to **Stoffella *et al.* (1984 and 1986)**. The genotypic stability was discussed by **Tai (1971)**, and proposed two stability measures (α_i and λ_i). The additive main effects and multiplicative interaction (AMMI) model were suggested by **Gauch, (1988 and 1992)**. The AMMI has proven useful for understanding complex G×E interactions. The AMMI stability value (ASV) was roposed by **Purchase (1997) and Purchase *et al.* (2000).** The AMMI and SREG models were used for obtaining the GE and GGE biplots, respectively. Biplots were used illustrate these relationships **(Gabriel, 1971 and Kempton, 1984).**

Therefore, the present investigation aimed to evaluate response of eight potato cultivars under two different planting seasons over three years at newly reclaimed soil. Partitioning the genotype by environment interaction to its stability parameters, *i.e.,* joint regression, genotypic stability, and AMMI and SREG methods.

MATERIALS AND METHODS

Eight potato cultivars were used for this work, their origin and characteristics are presented in Table 1. The field experiments were done at six growing seasons, three fall of 2013/2014, 2014/2015 and 2015/2016; and three summer of 2014, 2015 and 2016, under central pivot irrigation system at Vegetables Private Farm at Al-Salhyia, Fakous District, Sharkia Governorate, Egypt. Meteorological data for the three years of study (each include fall and summer) from October till June are presented in Table 2 according to Central Climatic Laboratory, Ministry of Agriculture, Egypt.

The soil type of those seasons was loamy sand with pH (7.8 - 8.2), EC (0.9 - 1.4) ds.m^{-1} and organic matter from 0.50-0.96%. Experimental design was split plot system in randomized complete block design with three replications. The different environments (two sowing seasons at three years) were considered main plots. The eight potato cultivars (genotypes) in each environment were randomly distributed on the subplots. Plot area was18 m^2, each plot consisted of two rows, 10 m long and 0.9 m a part. At plantation, tuber seed were spaced at 0.25 m within the row and sowed at 0.15 m depth. Sowing time was on Oct. 5th in each fall season of 2013/2014, 2014/2015 and 2015/2016 and on Feb. 10th in summer plantation of 2014, 2015 and 2016. Cultural practices for irrigation, fertilization and weed and pests control were done according to the recommendations of Ministry of Agriculture for central pivot sprinkle irrigation cultures. Treatments were harvested on range of Jan. 20th to Feb. 15th for each fall seasons and on May, 31st until June 15th in 2014, 2015 and 2016 summer seasons.

Data recorded

Ten whole plant samples per sub-plot were randomly used at harvest to determination these traits: aerial stem number/plant, tuber number/ plant, tuber yield/plant (kg) and/or per fad., (ton) and average tuber weight was calculated. Dry matter (%) in tubers was determined for each experimental unit of 200g oven dried at 70˚c tell constant value, at the experimental lab. at Hort. Dept., Fac. Agric., Zagazig Uinv.

Statistical analysis

Obtained data from each environment were statistically analyzed for the studied traits according to **Steel and Torrie (1997)**. When the G×E interactions found that significant, phenotypic stability analysis was computed as outlined by **Eberhart and Russell (1966)**, to get b_i and S^2d_i parameters. The determination coefficient of regression (R^2) was calculated according to **Stoffella *et al.* (1984 and 1986)**. The genotypic stability analysis was also calculated according to **Tai (1971)**, to estimate α_i and λ_i parameters, and additive main effects and multiplicative interaction method (AMMI) was computed as proposed by **Gauch (1992)**.

RESULTS AND DISCUSSION

Mean Performance

Analysis of variance

The combined analyses of variance for aerial stem number, tuber number/plant and tuber (kg/plant and tones/fad.), average tuber weight and tuber dry matter (%), showed highly significant differences among the studied factors; *i.e.,* environments and potato genotypes. Those results indicated that the genotypes were valid for studying their performance under these varied climatic (Table 3). The results indicated that the component of genotype × environment interaction (G×E) showed clear significant for the previously mentioned traits, except that for aerial stem number. Such information lead to proceed for regression analysis and to detected the degree of stability of those genotypes reflecting significance of the G×E interaction **(Eberhart and Russell, 1966)**.

The mean square of joint regression analysis of variance (Table 4), indicating the environment + genotype × env. (E+G×E) and both linear and non-linear (pooled deviation) components. The mean squares due to environment (linear) were highly significant for all traits, indicating the differences existed between environments and revealed predicted component and linear interaction (G×E linear) had highly significant when tested against pooled deviation for tuber number/plant, tuber yield/plant (kg) and (tones/fad., average tuber weight and tuber dry matter (%) for genotypes when grown at different planting times and years. Similar explanation was also reached by **Gruneberg *et al.* (2005)**, **Claiskan *et al.* (2007) and El-Sharkawy and Abd El-Aal (2013)**.

The analysis of variance in Table 5 show highly significant differences among genotypes, indicated that the evaluated cultivars differed in their genetic potentials concerning these characters. Most of traits under this investigation reflected clear significant effect of macro-environmental factors (years and sowing seasons), variability among seasons could mainly be related to differences in these plantations.

The year × planting season interaction (Y×S) not differ significantly for studied traits, except tuber yield/fad., trait was significant, indicating the different influences of climatic conditions of year on the two studied sowing seasons (fall and summer). Highly significant interaction between potato Genotype × year (G×Y) were reported for all traits, suggested that G×Y component accounted for the most part of total G×E, indicating that growing season had the most part of total G×E, indicating that growing season had the major effect on relative genotypic potential for these traits. On the other hand, the analysis of variance showed insignificant interactions between genotypes and growing seasons (G×S) for all traits, except tuber dry matter trait was significant. For the genotype × year × sowing season (G×Y×S) interactions, there were a differential response for tuber yield/fad., (ton) and tuber dry matter. These results reflected the importance of environmental factors on the performance of genotype. Similar results were obtained by **Moussa *et al.* (2011)** on sweet potato and **El-Sharkawy and Abd El-Aal (2013)** on potato in Egypt. On the other side, G×Y×S interactions were not significant for tuber yield/plant and its components.

Mean of different studied traits

Results in Tables 6 and 7 show significant differences for tuber yield and its component traits among the evaluated cultivars and reflect a large amount of variability. For tuber number/ plant, the values ranged from 11.573 for Caruso (G_1) in E_6 (summer planting at third year 2016) and Horaizon (G_3) in E_2 and E_6 (11.147 and 11.190, respectively) to 6.32 for Spunta (G_5) in E_1. While, the highest average tuber weight noticed with G_5 in E_6 (126.817) and the lowest value was 71.91 (g) with G_1 in E_3. Therefore, their ranks within environments indicated their specific adaptation which reflect the highly magnitude of genotype × environment interaction.

For tuber yield/plant and per fad., the values ranged from 1.128 kg/plant and 21.246 ton/fad., for Almondo (G_8) in E_6 to 0.575 kg/plant and 11.210 ton/fad., for Mondial (G_6) in E_1 for tuber yield/plant and for G_4 in E_1 for total tuber yield/fad. Similar results were showed by **Hassanpanah and Azimi (2010) and Abubaker *et al.* (2011)** on potato in Jordan.

Results in Table 8 show that tuber dry matter (%) of the studied potato cultivars ranged from 23.92% for Caruso (G_1) in E_6 to 17.64% for Spunta (G_5) in E_2. These results reported that, the cultivars from G_1 to G_4 were valid to processing objectives; while, the potato cvs from G_5 to G_8 classifated as table varieties. As similar result by **Abubaker *et al.* (2011)** reported that, Matador cv. was valid to processing and Spunta and Zafira for table and cocking objectives.

Table 1. Description of the eight potato cultivars and their origin and sources

Potato cultivar	Gene code	Origin	Introduced by	Objective	Maturity date
Caruso	G_1	Germany	Daltex Co.	Processing	Late
Hermus	G_2	Scotland	Daltex Co.	Processing	Medium
Horaizon	G_3	Scotland	Daltex Co.	Processing	Medium
Lady Rossetta	G_4	Holland	Daltex Co.	Processing	Medium
Spunta	G_5	Holland	Daltex Co.	Table	Early
Mondial	G_6	Holland	Exporters Union	Table	Late
Inova	G_7	Holland	Daltex Co.	Table	Medium
Almondo	G_8	Holland	Daltex Co.	Table	Medium

Table 2. Monthly meteorological data during the growing years of 2013/2014, 2014/2015 and 2015/2016 of study

Year	CMV	Oct.	Nov.	Dec.	Jan.	Feb.	Mars	April	May	June
2013/2014	**T (C°)**	21.85	20.01	13.32	13.62	14.28	17.21	21.53	25.33	28.09
	RH (%)	50.51	54.08	57.47	58.89	57.48	45.10	39.00	36.25	35.74
	W (km h^{-1})	4.27	3.40	3.71	2.99	3.66	3.99	3.80	4.02	4.19
	R (mm)	0.10	6.40	21.10	9.80	17.40	13.30	5.70	5.50	0.00
2014/2015	**T (C°)**	23.15	18.59	15.49	12.11	13.26	17.27	19.62	25.04	26.80
	RH (%)	49.52	57.48	55.23	51.63	48.46	49.12	39.98	36.07	40.42
	W (km h^{-1})	3.30	3.60	3.23	4.29	4.13	3.77	4.30	3.94	4.24
	R (mm)	4.90	12.00	10.00	27.30	33.50	8.60	6.10	1.80	0.00
2015/2016	**T (C°)**	24.73	19.40	14.25	11.57	15.63	17.93	23.10	25.26	30.12
	RH (%)	54.65	61.37	64.08	60.55	50.51	43.50	36.33	35.36	32.64
	W (km h^{-1})	3.57	3.60	3.69	3.89	3.60	4.19	4.07	4.42	4.17
	R (mm)	9.80	22.90	20.80	55.20	20.70	10.30	2.30	2.10	0.00

CMV: Climate mean values, according to Central Climatic Laboratory, Ministry of Agriculture, Egypt.

T: Temperature degree, RH: Relative humidity, W: Wind and R: Rainfall.

Table 3. The combined analyses of variance over environments and genotypes for the studied traits

SOV	d.f	Aerial stem No./plant	Tuber No./plant	Average tuber weight (g)	Tuber yield/plant (kg)	Tuber dry matter (%)	Tuber yield/fad. (ton)
Environments (E)	5	0.620^{**}	19.916^{**}	201.635^{**}	0.260^{**}	0.446^{**}	9.827^{**}
Reps/Env. (Error a)	12	0.036	0.225	6.005	0.002	0.016	0.617
Genotypes (G)	7	7.308^{**}	15.635^{**}	4582.125^{**}	0.168^{**}	105.863^{**}	74.068^{**}
Gen.×Env. (G×E)	35	0.086^{ns}	0.442^{*}	16.811^{*}	0.006^{**}	0.121^{**}	1.806^{**}
(Error b)	84	0.072	0.258	9.501	0.003	0.020	0.737

ns, * and **: Not significant, significant and highly significant at 0.05 and 0.01 levels of probability, respectively.

Table 4. Joint regression analysis of variance over environments and genotypes for tuber yield and its components and tuber dry matter percentage

SOV	d.f	Tuber No./plant	Average tuber weight(g)	Tuber yield/plant (kg)	Tuber dry matter (%)	Tuber yield/fad. (ton)
Model	47	1.592^{**}	239.124^{**}	0.019^{**}	5.301^{**}	7.346^{**}
Genotypes (G)	7	5.212^{**}	527.375^{**}	0.056^{**}	33.288^{**}	24.689^{**}
Environments (E)	5	6.639^{**}	70.212^{**}	0.087^{**}	0.149^{**}	30.276^{**}
G×E	35	0.147^{*}	5.604^{*}	0.002^{**}	0.040^{*}	0.602^{*}
E+G×E	40	0.959^{**}	13.680^{**}	0.013^{**}	0.054^{**}	4.311^{**}
Environments (linear)	1	24.895^{**}	263.294^{**}	0.325^{**}	0.557^{**}	113.534^{**}
G×E (linear)	7	1.370^{**}	28.390^{**}	0.019^{**}	0.098^{**}	5.975^{**}
Pooled deviation	32	0.121	2.661	0.001	0.028	0.534
Pooled error	96	0.086	3.167	0.001	0.007	0.246

*, **: Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.

Table 5. The analysis of variance for the studied traits over years and sowing seasons for potato genotypes

SOV	d.f	Tuber No./plant	Average tuber weight (g)	Tuber yield/plant (kg)	Tuber yield/fad. (ton)	Tuber dry matter (%)
Environment (E)	5	19.916^{**}	210.635^{**}	0.260^{**}	90.827^{**}	0.446^{**}
Reps/Env. (Error a)	12	0.225	6.005	0.002	0.617	0.016
Year (Y)	2	3.242^{**}	344.673^{**}	0.094^{**}	30.120^{**}	1.060^{**}
Year×Season (Y×S)	2	0.573^{ns}	0.194^{ns}	0.003^{ns}	2.429^{*}	0.008^{ns}
Sowing season (S)	1	91.953^{**}	363.442^{**}	1.105^{**}	389.039^{**}	0.093^{*}
Genotypes (G)	7	15.635^{**}	4582.125^{**}	0.168^{**}	74.068^{**}	105.863^{**}
Gen.×Env. (G×E)	35	0.442^{*}	16.811^{*}	0.006^{**}	1.806^{**}	0.121^{ns}
Gen.×Year (G×Y)	14	0.657^{**}	39.782^{**}	0.011^{**}	3.917^{**}	0.239^{**}
Gen. ×Season (G×S)	7	0.420^{ns}	2.564^{ns}	0.004^{ns}	0.594^{ns}	0.053^{*}
G×Y×S	14	0.238^{ns}	0.962^{ns}	0.002^{ns}	0.302^{**}	0.036^{*}
Pooled Error (Error b)	84	0.258	9.501	0.003	0.737	0.020

ns, *, **: Not significant, significant and highly significant at 0.05 and 0.01 levels of probability, respectively.

Table 6. Mean performance for tuber number/plant and average tuber weight (g) of the eight potato cultivars under different environments

Genotype	2013/2014		2014/2015		2015/2016	
	Fall E_1	Summer E_2	Fall E_3	Summer E_4	Fall E_5	Summer E_6
			Tuber number/plant			
Caruso (G_1)	8.773	10.727	8.837	10.500	9.673	11.573
Hermus (G_2)	7.047	8.507	7.797	8.607	7.690	9.130
Horaizon (G_3)	9.000	11.147	9.140	10.977	9.370	11.190
Lady Rossetta (G_4)	7.827	9.370	7.667	9.553	7.807	9.200
Spunta (G_5)	6.323	7.837	7.183	7.940	6.860	8.280
Mondial (G_6)	7.890	9.900	7.653	9.227	8.507	8.777
Inova (G_7)	7.027	9.317	7.570	8.917	8.213	9.817
Almondo (G_8)	7.520	9.407	8.647	10.487	8.883	10.877
Mean	7.676	9.526	8.062	9.526	8.375	9.855
LSD $_{0.05}$ (G)	0.838	0.899	0.902	0.999	0.961	0.708
LSD $_{0.05}$						
Years (Y) =		0.206	$G \times Y =$		0.584	
$Y \times S =$		0.292	$G \times S =$		0.477	
Sowing season (S)		0.168	$G \times Y \times S =$		0.825	
			Average tuber weight (g)			
Caruso (G_1)	73.783	76.283	71.913	74.000	72.543	74.783
Hermus (G_2)	102.147	106.240	108.570	111.657	108.537	112.223
Horaizon (G_3)	85.913	89.417	89.200	90.673	88.473	91.750
Lady Rossetta (G_4)	76.983	79.910	77.540	80.973	76.467	79.950
Spunta (G_5)	115.477	118.733	119.043	123.427	120.583	126.817
Mondial (G_6)	73.100	76.507	78.950	82.467	83.087	86.333
Inova (G_7)	93.290	96.493	94.277	98.090	100.700	102.973
Almondo (G_8)	89.073	91.587	93.883	96.500	101.687	103.690
Mean	88.721	91.896	91.672	94.723	94.010	97.315
LSD $_{0.05}$ (G)	6.031	5.627	6.064	6.598	4.000	3.241
LSD $_{0.05}$						
Years (Y) =		1.252	$G \times Y =$		3.541	
$Y \times S =$		1.771	$G \times S =$		2.892	
Sowing season (S)		1.022	$G \times Y \times S =$		5.008	

Table 7. Mean performance for tuber yield/plant (g) and tuber yield/fad. (ton) of the eight potato cultivars under different environments

Genotype	2013/2014		2014/2015		2015/2016	
	Fall E_1	Summer E_2	Fall E_3	Summer E_4	Fall E_5	Summer E_6
			Tuber yield/plant (g)			
Caruso (G_1)	0.691	0.818	0.636	0.778	0.701	0.865
Hermus (G_2)	0.719	0.921	0.844	0.968	0.822	1.025
Horaizon (G_3)	0.773	0.997	0.815	0.995	0.829	1.029
Lady Rossetta (G_4)	0.612	0.759	0.595	0.773	0.597	0.736
Spunta (G_5)	0.730	0.931	0.853	0.980	0.827	1.050
Mondial (G_6)	0.575	0.756	0.603	0.760	0.708	0.758
Inova (G_7)	0.657	0.865	0.713	0.874	0.803	1.011
Almondo (G_8)	0.670	0.904	0.812	1.012	0.903	1.128
Mean	0.678	0.869	0.734	0.893	0.774	0.950
LSD $_{0.05}$ (G)	0.102	0.085	0.074	0.109	0.089	0.074
LSD $_{0.05}$						
Years (Y) =		0.021	G × Y =		0.059	
Y × S =		0.029	G × S =		0.048	
Sowing season (S)		0.017	G × Y × S =		0.083	
			Tuber yield/fad. (ton)			
Caruso (G_1)	12.832	16.207	12.970	15.368	13.962	17.095
Hermus (G_2)	14.323	17.858	17.125	18.971	16.478	19.731
Horaizon (G_3)	15.351	19.550	15.999	19.599	16.370	20.142
Lady Rossetta (G_4)	11.210	14.988	12.011	14.217	11.689	14.455
Spunta (G_5)	14.563	18.396	17.061	19.296	16.546	20.612
Mondial (G_6)	11.444	14.756	11.383	14.732	12.015	14.856
Inova (G_7)	13.811	17.720	14.065	17.283	16.251	19.568
Almondo (G_8)	13.306	17.039	16.084	19.745	17.685	21.246
Mean	13.355	17.064	14.587	17.401	15.125	18.463
LSD $_{0.05}$ (G)	1.312	1.860	1.358	1.716	1.390	1.291
LSD $_{0.05}$						
Years (Y) =		0.349	G × Y =		0.986	
Y × D =		0.493	G × S =		0.805	
Sowing season (S)		0.285	G × Y × S =		1.395	

Table 8. Mean performance of the eight potato cultivars under environment for tuber dry matter (%)

Genotype	2013/2014		2014/2015		2015/2016	
	Fall E_1	Summer E_2	Fall E_3	Summer E_4	Fall E_5	Summer E_6
G 1	23.760	23.803	23.660	23.750	23.803	23.920
G 2	23.040	23.030	22.907	22.940	23.053	22.967
G 3	22.517	22.537	22.810	22.790	22.747	22.957
G 4	22.873	22.963	23.113	23.077	22.927	23.063
G 5	17.910	17.640	18.173	18.097	18.240	18.087
G 6	18.180	18.310	18.623	18.623	18.737	18.860
G 7	18.520	18.930	18.770	19.030	19.017	18.987
G 8	19.217	18.967	18.630	18.890	19.650	19.877
Mean	20.752	20.773	20.836	20.900	21.022	21.090
LSD $_{0.05}$ (G)	0.232	0.371	0.216	0.215	0.165	0.219
LSD $_{0.05}$						
Years (Y) =		0.057	G × Y =		0.161	
Y × S =		0.080	G × S =		0.131	
Sowing season (S)		0.046	G × Y × S =		0.227	

Stability Parameters

Tuber number per plant

The importance of both linear (b_i) and non-linear (S^2d_i) with average cultivar ($\bar{g}_i$), determined phenotypic stability of a cultivar sensitivity for the expression of genotype under specific environment. Results in Table 9 reveal that, according to phenotypic stability, b_i values deviated significantly from unity ($b_i > 1$) and lowest S^2di, the best stable genotypes were G_3 and G_1 with $\bar{g}_i$=10.14 and 10.01, these cultivars (Horaizon and Caruso) could be useful in potato breading programs for improve this trait under different seasons and years. The genotype with high values of R^2 were also considered desirable as G_3, G_7, G_1 and G_4.

Moreover, genotypic stability parameters; linear response to environmental effects (α_i) and the deviation from linearity (λ_i). Perfectly stable potato genotype probably do not exist, potato breeders will have to be satisfied with the accessible levels of stability; *i.e.,* average stability α_i=0.0 and λ_i=1, below average stability $\alpha_i > 0$ and $\lambda_i = 1$ and above average stability $\alpha_i <0$ and λ_i= 1. Table 9 and Fig. 1 showed that all studied genotypes were stable and insignificant for (α_i), as well as for (λ_i), except Mondial (G_6) and Almondo (G_8).

According to additive main effects and multiplicative interaction method (AMMI) stability value (ASV) and its ranking value (Table 9 and Fig. 1), the smallest AMMI stability value of the genotypes Horaizon (G_3), Hermus (G_2), Inova (G_7) and Spunta (G_5) were more stable (0.39, 0.54, 0.59 and 0.60, respectively), while the genotypes Mondial (G_6), Almondo (G_8) and Lady Rossetta (G_4) were unstable. In Table 10, the IPCA scores of a potato genotypes in the AMMI analysis were significant for IPCA1, only (55.89%). Variance components (%) of mean of squares varied from 43.98% for genotypes, 40.02% for environments and 6.21% for GEI. For assessing the environments according to their position from origin (Fig. 2), the potato genotypes and environments that were located far away from the origin more responsive. Environments E_1, E_2, E_3 and E_6 were the most differencing environments, while environments E_4 and E_5 were less reactive. Furthermore, the Vertex potato genotypes G_5, G_8, G_1, G_6 and G_5 were located far away from orgin, which were more responsive to environment change and are considered as specifically adapted potato genotypes, as they have the longest distance from the origin in their direction and potato genotypes with long vectors were assigned as either the best or the poorest performers in the environment. The potato cultivers G_7, G_3, G_2 and

Table 9. Genotype means over six environments and stability parameters of the eight potato genotypes for tuber number/plant

Genotype	Mean ($\bar{g}_i$)	P_i	b_i	S^2_{di}	R^2	α_i	λ_i	ASV	Ranking
Caruso (G_1)	10.014	1.177	1.187	0.093	0.940	0.189	0.984	0.82	5
Hermus (G_2)	8.129	-0.707	0.802	0.045	0.936	-0.201	0.477	0.54	2
Horaizon (G_3)	10.137	1.300	1.155	0.042	0.970	0.157	0.447	0.39	1
Lady Rossetta (G_4)	8.571	-0.266	0.913	0.125	0.874	-0.088	1.328	0.97	6
Spunta (G_5)	7.404	-1.433	0.780	0.057	0.917	-0.222	0.604	0.60	4
Mondial (G_6)	8.659	-0.178	0.749	0.293*	0.665	-0.254	3.107*	2.12	8
Inova (G_7)	8.477	-0.360	1.146	0.060	0.958	0.148	0.634	0.59	3
Almondo (G_8)	9.303	0.467	1.268	0.250*	0.870	0.271	2.648*	1.95	7
Mean $\bar{\bar{X}}$	8.837								
LSD	0.337								
CV (%)	3.319								

$\bar{g}_i$ = mean of genotypes, Pi = phenotypic index ($\bar{g}_i - \bar{\bar{X}}$), bi = regression coefficient, S^2di = mean square deviations from linear reggrisson, α_i = liner response.

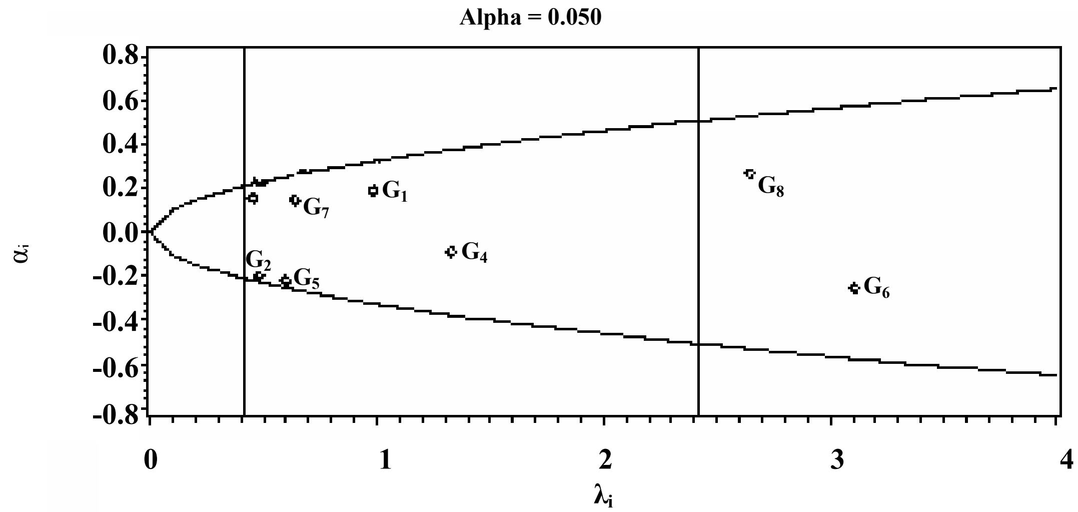

Fig. 1. Genotypic stability parameters (α_i and λ_i) for 8 potato genotypes of tuber number/plant

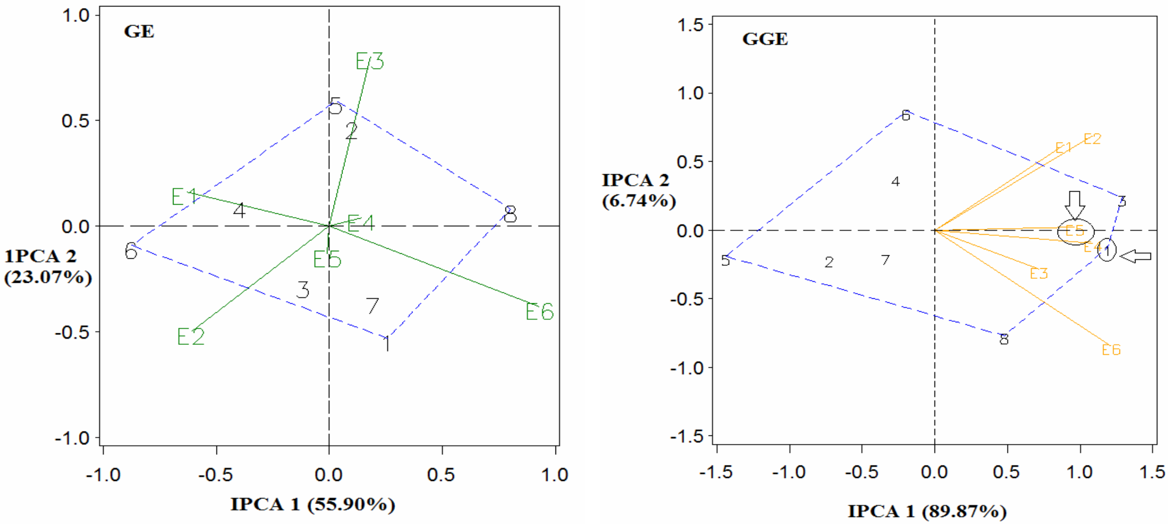

Fig. 2. Graphics display of GE and GGE biplots of 8 potato genotypes (assessed G_1-G_8) and six environments (assessed E_1–E_6) in the AMMI and SREG models, respectively for tuber number/plant

G_4 were the desirable, they located near the origin and less responsive than corner potato genotypes.

Concerning GGE biplot for the SREG model show that the potato cultivar should have highest mean performance and zero IPCAZ for tuber number/plant be absolutely stable. Thus, caruso (G1) was ideal potato genotype (Fig. 2) and E_5 was ideal environment. Similar results reported by **Hassanpanah and Azimi (2010)** on potato in Iran.

Average tuber weight

Results in Table 11 show that, Spunta cv scored highest value (120.68 g), bi= 1.315 and S^2di= 0.719. It also had high value of R^2= 0.963 and considered stable for phenotypic stability under different seasons. For genotypic stability parameters, the both cultivars G_5 and G_3 in average stability (Table 11 and Fig. 3).

According to ASV and its ranking (Table 11), the smallest value was recorded with Hermus and Spunta (1.73 and 2.03, respectively). Table (10), show that IPCA scores of a potato cultivars in the AMMI analysis were significant for IPCA1, and 2 (the present were 43.65 and 93.71 respectively). Variance components (%) of mean squares were 92.74% for genotypes, 3.05% for environments and 1.70 for GEI. GE biplot graph for the AMMI indicated that, most environments differenting for average tuber weight, the potato genotypes G_3 and G_5 were the most desired and stable for this traits. Based on GGE biplot for the SREG model showed that, Hermus (G_2) was ideal genotype for average tuber weight, it had the highest vector length of the higher potato genotype and with zero GE, as represented by the mark with an arrow pointing to it in (Fig. 4). The environment E_1 with E_2, E_6 with E_5, E_3 with E_4 and were positively correlated because all angles among them were smaller than 90°.

Tuber yield/plant

Results of phenotypic stability parameters (Table 12) showed that the highest $\bar{g}_i$ was G_3 and G_8, the (bi) values were not deviated significantly from unity and S^2di values were not significantly different from zero, except G_4 and G_8, therefore these genotypes more phenotypic stable than others under studied environments for this trait. G_3, G_7, G_2 and G_5 had highest values of R^2 and considered desirable. For genotypic stability parameters (Table 12 and Fig. 5) showed that all potato cultivars were stable and insignificant for the two stability measures (α_i and λ_i).

A potato genotype with least ASV is the most stable, in respect to tuber yield/plant as given in Table 12, the genotypes Horaizon, Hermus, Spunta and Mondial were most desired and stable for this trait (0.26, 0.28, 0.35 and 0.49,

Table 10. AMMI analysis of variance over six environments (three years and two sowing seasons) for the studied traits

Source of variation	d.f	Tuber No./plant		Average tuber weight (g)		Tuber yield/plant (g)		Tuber yield/fad. (ton)		Tuber dry mature (%)	
		MS	(%)	MS	(%)	MS	(%)	MS	(%)	MS	(%)
Environment (E)	5	19.92**	40.02	210.64**	3.05	0.260**	44.20	90.83**	41.09	0.45**	0.30
Reps / Env.	12	0.22		6.00		0.002		0.62		0.02	
Genotype (G)	7	15.63**	43.98	4582.12**	92.74	0.168**	40.07	74.07**	46.91	105.86**	98.89
G x E	35	0.44*	6.21	16.81*	1.70	0.006**	7.28	1.81**	5.72	0.12**	0.56
IPCA1	11	0.79**	55.89	43.65**	81.60	0.013**	68.63	3.92**	68.23	0.24**	62.87
IPCA2	9	0.40	23.07	9.71**	14.85	0.004	16.12	1.56*	22.25	0.10**	21.94
IPCA3	7	0.29	13.18	2.34	2.78	0.003	9.84	0.56	6.16	0.07**	11.06
IPCA4	5	0.18	5.87	0.70	0.59	0.002	3.77	0.35	2.80	0.03	3.88
IPCA5	3	0.10	1.97	0.34	0.18	0.001	1.50	0.12	0.56	0.00	0.22
Pooled Error	84	0.26		9.50		0.00		0.74		0.02	

*, ** significant at 0.05 and 0.01 levels of probability, respectively.

AMMI: The additive main effects and multiplicative interaction method.

Table 11. Genotype means over six environments and stability parameters of the eight potato genotypes for average tuber weight (g)

Genotype	Mean ($\bar{g}_i$)	P_i	b_i	S^2_{di}	α_i	λ_i	R^2	ASV	Ranking
Caruso (G_1)	73.884	-19.172	0.071**	3.012	-0.956*	0.789	0.018	10.37	7
Hermus (G_2)	108.229	15.173	1.167	2.268	0.172	0.652	0.868	1.73	1
Horaizon (G_3)	89.238	-3.818	0.607*	0.973	-0.405*	0.267*	0.806	4.63	4
Lady Rossetta (G_4)	78.637	-14.419	0.333*	3.144	-0.686*	0.866	0.279	8.65	6
Spunta (G_5)	120.680	27.624	1.315*	0.719	0.324*	0.198*	0.963	2.03	2
Mondial (G_6)	80.074	-12.982	1.583	1.675	0.600*	0.452	0.943	7.02	5
Inova (G_7)	97.637	4.581	1.167	2.441	0.172	0.702	0.860	2.89	3
Almondo (G_8)	96.070	3.014	1.757	7.056	0.779	1.984	0.828	10.90	8
Mean	93.056								
LSD	2.045								
CV (%)	1.912								

Table 12. Genotype means over six environments and stability parameters of the eight potato genotypes for tuber yield / plant

Genotype	Mean ($\bar{g}_i$)	P_i	b_i	S^2_{di}	α_i	λ_i	R^2	ASV	Ranking
Caruso (G_1)	0.748	-0.068	0.753	0.0017	-0.249	1.781	0.818	0.72	6
Hermus (G_2)	0.883	0.067	1.033	0.001	0.033	0.850	0.947	0.28	2
Horaizon (G_3)	0.906	0.090	1.055	0.001	0.055	0.768	0.953	0.26	1
Lady Rossetta (G_4)	0.678	-0.138	0.715	0.002*	-0.288	2.383	0.751	1.00	7
Spunta (G_5)	0.895	0.079	1.077	0.001	0.077	0.911	0.947	0.35	3
Mondial (G_6)	0.693	-0.123	0.742	0.001	-0.260	1.336	0.853	0.49	4
Inova (G_7)	0.821	0.004	1.183	0.001	0.185	1.001	0.952	0.52	5
Almondo (G_8)	0.905	0.089	1.443	0.003*	0.447	3.184	0.902	1.35	8
Mean	0.816								
LSD	0.034								
CV (%)	3.626								

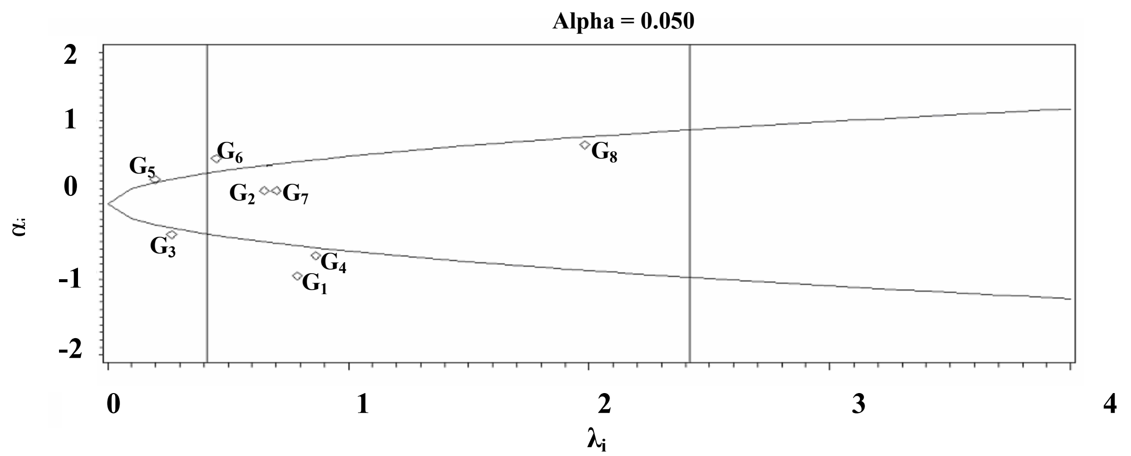

Fig. 3. Genotypic stability parameters (α_i and λ_i) of 8 potato genotypes for average tuber weight

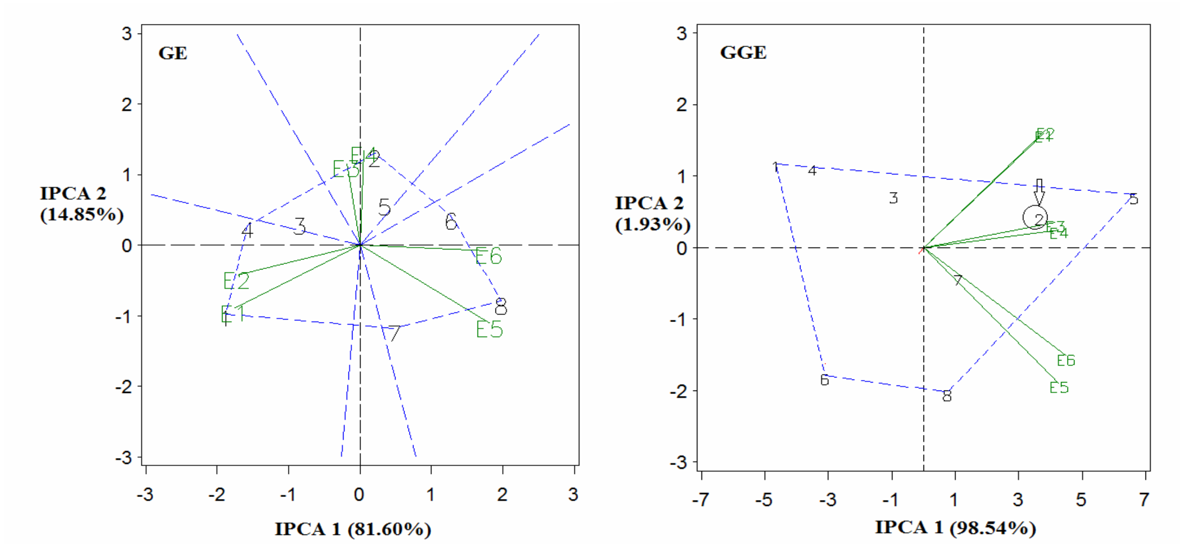

Fig. 4. Graphs display of the GE and GGE biplots of 8 potato genotypes (assessed G_1-G_8) and six environments (assessed E_1-E_6) in the AMMI and SREG models, respectively for average tuber weight

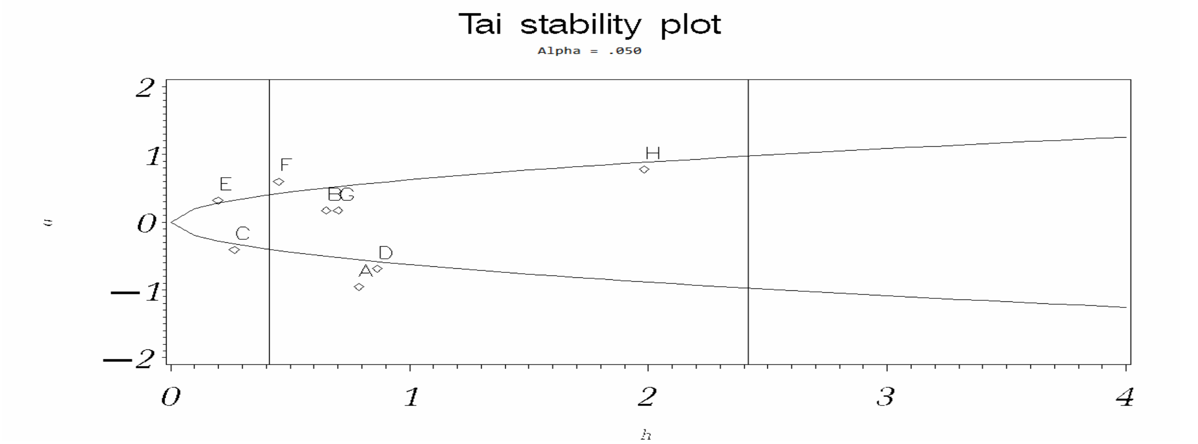

Fig. 5. Genotypic stability parameters (a_i and λ_i) of 8 potato genotypes for tubers yield/plant

respectively), whereas genotypes Lady Rossetta and Almondo where unstable and more responsive to the environmental changes. The IPCA scores of potato genotypes in the AMMI model were significant for IPCA1 only (68.63%). Variance components (%) of mean squares varied from 40.07 for potato genotypes, 44.20% for environments and 7.28% for GEI. Moreover, for SREG model. IPCA1 score exhibited 91.42% and ICPA2 had 5.32% of the total GGEI. (Table 10 and Fig. 6).

Tuber yield (ton/fad.)

The desirable and stable potato genotypes according to three stability parameters ($\bar{g}_i$, b_i and S^2d_i) for tuber yield/fad. Were Horaizon (G_3) with a mean yield $\bar{g}_i$ = 17.835 ton, b_i=1.079 and S^2d_i= 0.253); Spunta (G_5) ($\bar{g}_i$ = 17.746 ton, b_i = 1.076 and S^2d_i = 0.293) and Hermus (G_2) ($\bar{g}_i$= 17.414 ton, b_i= 0.939 and S^2d_i= 0.456). These genotypes gave mean values above grand mean and their regression coefficient (bi) did not differ significantly from unity, also minimum deviation mean squares (S^2di) were detected. Furthermore, these results showed that the potato cultivars G_3, G_5 and G_2 proved be widely adapted genotypes for climatic and newly reclaimed sandy soils conditions. According to determination coefficient or regression R, G_3, G_5 and G_1 had highest values and considered stable (Table 12). For genotypic stability parameters (α_i and λ_i), the cultivars Inova, genotypes Hermus, Spunta and Horaizon in average stability (Table 13 and Fig. 8).

According to ASV and its ranking (Table 13), the smallest values were recorded with G_7, G_3 and G_5 (1.01, 1.05 and 1.27, respectively). Table 10 show that IPCA scores of a potato in the AMMI models were highly significant for IPCA1 (68.23%) and significant for IPCA2 (22.25%). Variance components (%) of mean squares varied from 74.04% for potato genotypes, 41.09% for environments and 5.72% for GEI.

Tuber dry mater (%)

Phenotypic stability parameters (Table 14) showed that the highest ($\bar{g}_i$) were 23.783, 23.00 and 22.989 for Caruso, Lady Rossetta and Hermus. The genotypes Horaizon and Mondial had (bi) values were not deviated significantly from unity and S^2di values were not significantly different from zero, therefore these genotypes are more phenotypic desirable than others under studied environments. Also, G_6 and G_3 had highest values of the determination coefficient of regression (R^2) and considered stable.

For genotypic stability parameters, Horaizon and Mondial cultivars are in average stability (Table 14 and Fig. 9). According to ASV and its ranking (Table 14), the smallest values were recorded with G_1, G_7, G_3 and G_6 (0.31, 0.37, 0.42 and 0.43, respectively). Table (10), show that IPCA scores of a potato in AMMI model was highly significant for IPCA1, 2 and 3. Variance components (%) of mean squares varied from 98.89 for potato genotypes, 0.30% for environment and 0.56% for GEI. Fig. 10 show G_2 (Hermus) was ideal cultivar for tuber dry matter trait.

For CV% in all studied traits the results recorded that faw percentage of coefficient of varation, suggesting that genetic variation is dominant.

Table 13. Genotype means over six environments and stability parameters of the eight potato genotypes for tuber yield/fad. (ton)

Genotype	Mean ($\bar{g}_i$)	P_i	b_i	S^2_{di}	R^2	α_i	λ_i	ASV	Ranking
Caruso (G_1)	14.739	-1.260	0.871	0.284	0.927	-0.130	1.054	1.44	5
Hermus (G_2)	17.414	1.415	0.939	0.456	0.901	-0.061	1.698	1.30	4
Horaizon (G_3)	17.835	1.836	1.079	0.253	0.956	0.080	0.941	1.05	2
Lady Rossetta (G_4)	13.095	-2.904	0.776	0.500	0.851	-0.226	1.856	2.54	7
Spunta (G_5)	17.746	1.747	1.076	0.293	0.949	0.076	1.088	1.27	3
Mondial (G_6)	13.197	-2.802	0.852	0.387	0.899	-0.149	1.437	2.00	6
Inova (G_7)	16.450	0.450	1.095	0.506	0.918	0.096	1.883	1.01	1
Almondo (G_8)	17.518	1.518	1.311	1.593**	0.836	0.314	5.915*	4.46	8
Mean	15.999								
LSD	0.570								
CV (%)	3.098								

Table 14. Genotype means over six environments and stability parameters of the eight potato genotypes for tuber dry mature (%)

Genotype	Mean ($\bar{g}_i$)	P_i	b_i	S^2_{di}	R^2	α_i	λ_i	ASV	Ranking
Caruso (G_1)	23.783	2.888	0.400*	0.005	0.409	-0.623*	0.708	0.31	1
Hermus (G_2)	22.989	2.094	-0.042**	0.004	0.009	-1.081*	0.494	0.51	5
Horaizon (G_3)	22.726	1.831	1.033	0.011	0.686	0.034	1.588	0.42	3
Lady Rossetta (G_4)	23.003	2.108	0.208*	0.010	0.088	-0.823*	1.374	0.86	7
Spunta (G_5)	18.024	-2.871	1.016	0.036**	0.402	0.017	4.999*	0.54	6
Mondial (G_6)	18.556	-2.340	1.747	0.013	0.844	0.776	1.773	0.43	4
Inova (G_7)	18.876	-2.020	0.976	0.027**	0.449	-0.025	3.793*	0.37	2
Almondo (G_8)	19.205	-1.690	2.662*	0.120**	0.579	1.725	16.406*	2.53	8
Mean	20.895								
LSD	0.093								
CV (%)	0.387								

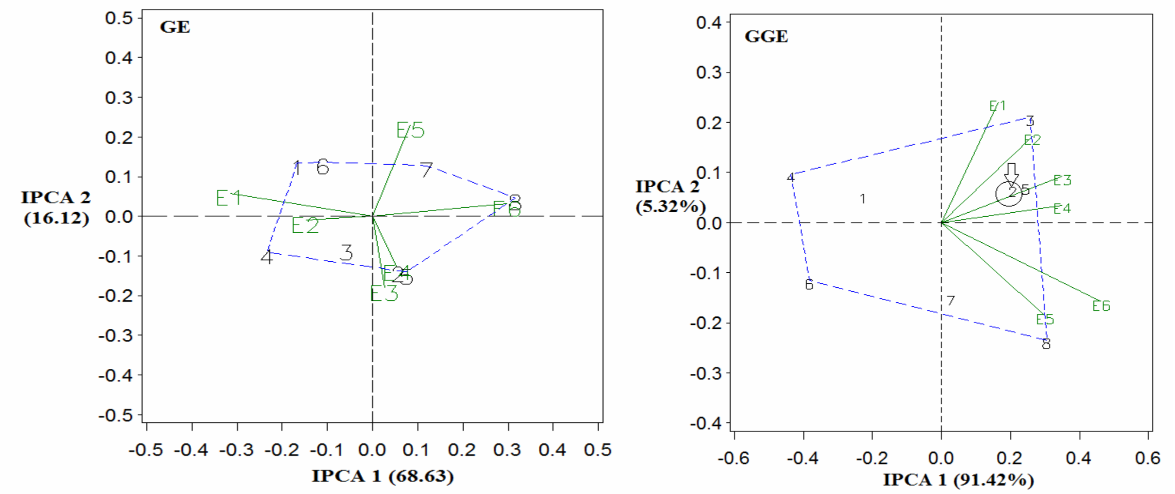

Fig. 6. Graphs display of the GE and GGE biplots of 8 potato genotypes (assessed G_1-G_8) and six environments (assessed E_1-E_6) in the AMMI and SREG models, respectively for tuber yield/plant

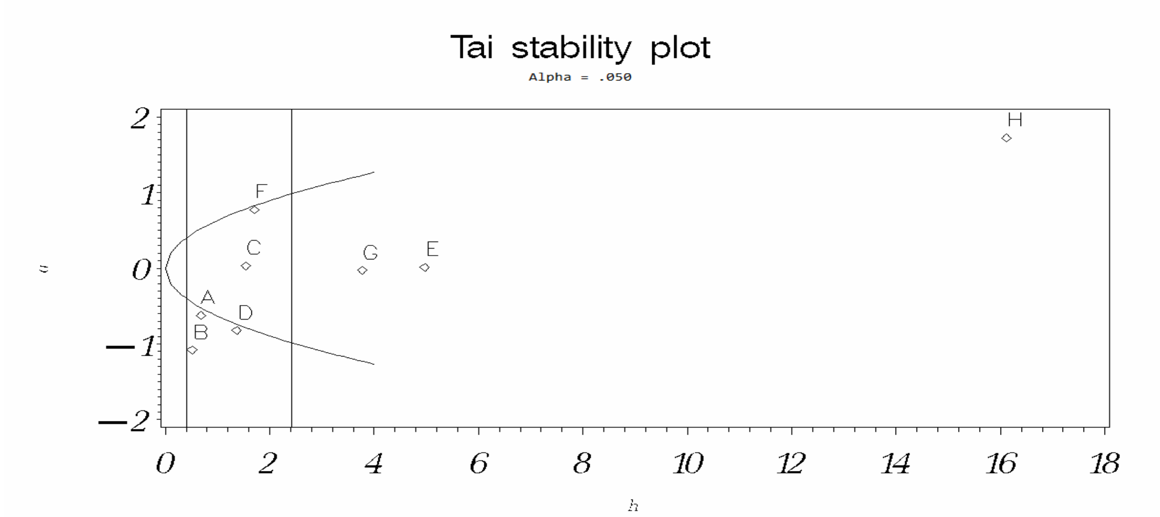

Fig. 7. Genotypic stability parameters (a_i and λ_i) of 8 potato genotypes for tuber yield/fad. (ton)

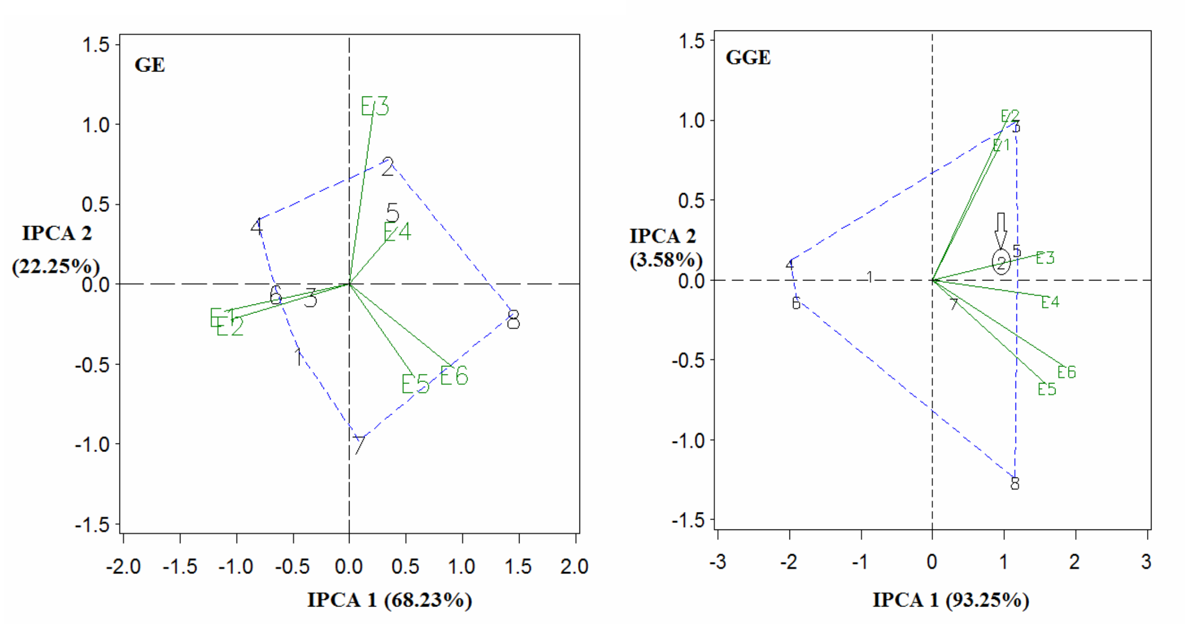

Fig. 8. Graphs display of the GE and GGE biplots of 8 potato genotypes (assessed G_1-G_8) and six environments (assessed E_1-E_6) in the AMMI and SREG models, respectively for tuber yield/fad. (ton)

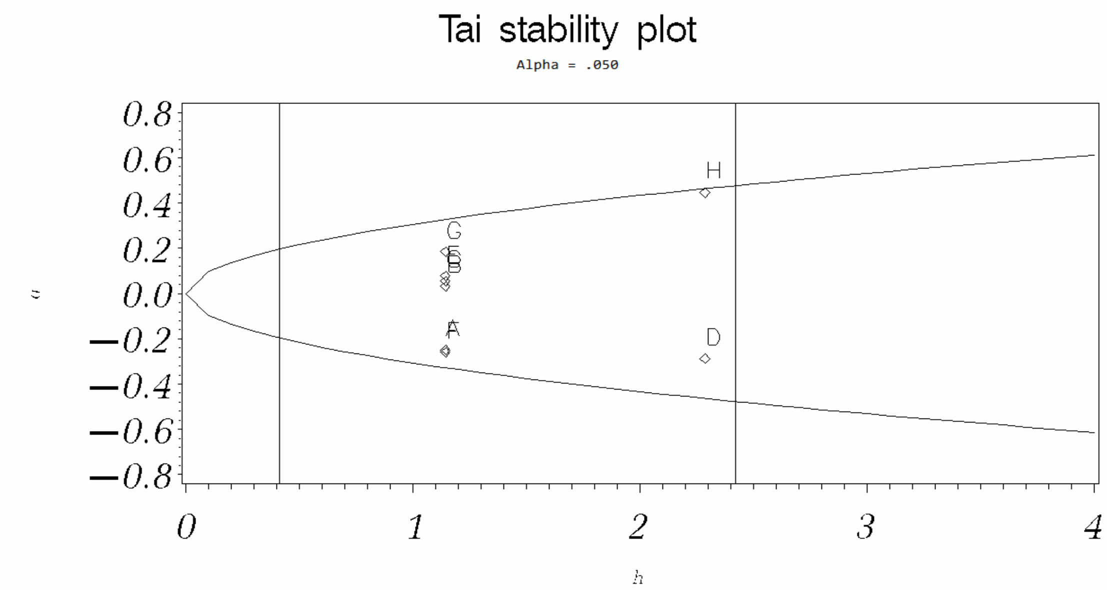

Fig. 9. Graphs display of the GE and GGE biplots of 8 potato genotypes (assessed G_1-G_8) and six environments (assessed E_1-E_6) in the AMMI and SREG models, respectively for tuber dry matter (%)

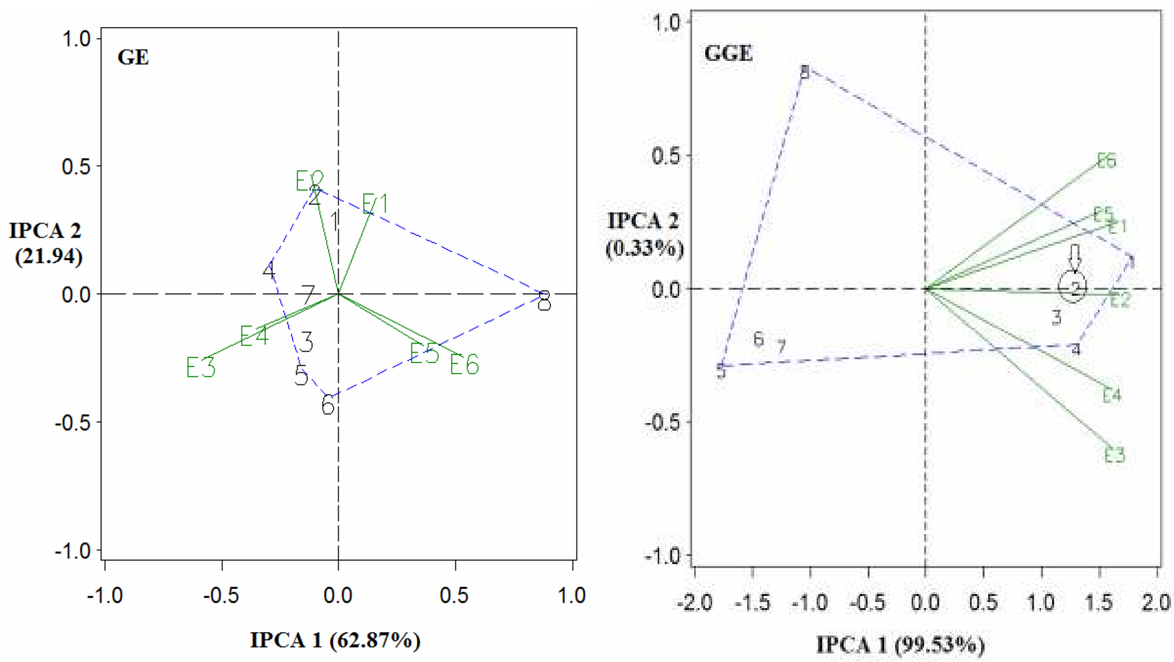

Fig. 10. Graphs display of the GE and GGE biplots of 8 potato genotypes (assessed G_1-G_8) and six environments (assessed E_1-E_6) in the AMMI and SREG models, respectively for tuber dry matter (%)

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تقدير مقاييس الثبات للتراكيب الوراثية للبطاطس تحت ظروف مواسم زراعة مختلفة

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أجريت هذه الدراسة في مزرعة خضر خاصة، الصالحية، فاقوس، الشرقية، مصر بهدف تقييم ثمانية تراكيب وراثية من البطاطس لصفات محصول الدرنات ومكوناته ونسبة المادة الجافة تحت ظروف ستة بيئات مختلفة هي التوليفات من ثلاث سنوات (٢٠١٣/٢٠١٤، ٢٠١٤/٢٠١٥، ٢٠١٥/٢٠١٦) وموسمي زراعة (الخريفي والصيفي)، أظهرت تحليلات التباين وجود اختلافات عالية المعنوية بين التراكيب الوراثية والبيئات وكذلك التفاعل بينهما لكل الصفات المدروسة ما عدا صفة عدد السيقان الهوائية/نبات، وفقاً لمقاييس الثبات المظهري أظهرت تراكيب البطاطس هواريزون وسبونتا أن لها قدرة تكييف عالية مع البيئات المثلى، هذه النتائج تعكس أهمية العوامل البيئية علي سلوك التركيب الوراثي، بالنسبة لمقاييس الثبات الوراثي كانت الأصناف هواريزون وهيرمس وسبونتا والوفا الأكثر ثباتا لقيمة ASV وR^2 في معظم الصفات، أظهر تحليل التفاعل للتركيب الوراثي + التركيب الوراثي × البيئة (GGE) أن التركيب الوراثي النموذجي كان الصنف كاروز لصفة عدد الدرنات/نبات والصنف هيرمس لصفات متوسط وزن الدرنة في محصول الدرنات/نبات ومحصول الدرنات/فدان ونسبة المادة الجافة للدرنات.

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