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Estimating Rank and Stability of Potato Cultivars by Nonparametric Stability Analysis

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Abstract: This experiment were conducted with three cultivars of potato such as Agria, Satina and Caesar and four irrigation regimes (after 30 mm evaporation from class A evaporation pan, after 30 mm evaporation from class A evaporation pan with spraying by potassium humate, after 60 mm evaporation with spraying by potassium humate and after 60 mm evaporation from class A evaporation pan) in three locations of Ardabil in Northwestern Iran during 2007-2008 with split plot method. Potassium humate sprayed (250 mL ha^{-1}) in the three stages of emergence, before tuberization and during tuberization period. Combined analysis of variance showed that were significant differences between locations, years, irrigation regimes and cultivars and their interaction on tuber yield. According to the $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ and $NP_i^{(5)}$ methods, Satina and Caesar were stable but Agria unstable and had the lowest value. Caesar cultivar is most stable and adapted across environments well; the highest mean of rank and yield and high ranking under normal, stress with potassium humate and stress conditions. In this study nonparametric statistics ($S_i^{(1)}$) selected.

Key words: Nonparametric, potato, potassium humate, stress

INTRODUCTION

Potato, *Solanum tuberosum* L. is grown and eaten in greater countries more than some other crops (Hassanpanah, 2009; Stephen, 1999). Among the most important crops in the world (Fernie and Willmitzer, 2001) and Iran (FAO, 2008), potato is ranked in fourth grade in annual production after the cereal species rice, wheat and barley. Iran is the world's 12th potato producer and the third biggest producer in Asia, after China and India's mentioned above (FAO, 2008).

Genotype by environment interactions are important sources of variation in any crop and the term stability is sometimes used to characterize a genotype, which shows a relatively constant yield, independent of changing environmental conditions. On the basis of this idea, genotypes with a minimal variance for yield across different environments are considered stable (Sabaghnia *et al*., 2006). Sabaghnia *et al*. (2006), Flores *et al*. (1998) and Lin *et al*. (1986) resulted that use of nonparametric stability models. Firstly, these methods avoid the bias caused by outliers and no assumptions are needed about the distribution of the observations. Secondly, these methods are easy to use and to interpret; therefore, estimation of stability seems to be an appropriate approach.

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Nonparametric procedures proposed by Nassar and Huhn (1987), Kang (1988), Fox *et al.* (1990), Thennarasu (1995), Huhn (1996) and Sabaghnia *et al.* (2006). The methods of Huhn (1996) and Kaya and Taner (2002) classified genotypes as stable or unstable in a similar fashion.

Nassar and Huhn (1987) and Huhn (1996) reported four nonparametric measures of phenotypic stability are as; (1) $S_i^{(1)}$ is the mean of the absolute rank differences of a genotype over the n environments (2) $S_i^{(2)}$ is the variance among the ranks over the n environments (3) $S_i^{(3)}$ and $S_i^{(4)}$ are the sum of the absolute deviations and sum of squares of rank for each genotype relative to the mean of ranks, respectively. Thennarasu (1995) proposed as stability measures the nonparametric statistics $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$ and $NP_i^{(4)}$ based on ranks of adjusted means of the genotypes in each environment and defined stable genotypes as those whose position in relation to the others remained unaltered in the set of environments assessed.

The objectives of this study were to interpret G×E interaction obtained by nonparametric statistical of yield performances of three potato cultivars and four irrigation regimes in six environments visually assess how to vary yield performances across environments based on the biplot and determine cultivars with high yields, depending on the differential genotypic responses to environments.

MATERIALS AND METHODS

This experiment were conducted on the three cultivars of potato and four irrigation regimes in Iran for two years (2007-2008). Experimental design was split plot with three replications. Factor A was four irrigation regimes [after 30 mm evaporation from class A evaporation pan, after 30 mm evaporation from class A evaporation pan with spraying by potassium humate, after 60 mm evaporation with spraying by potassium humate and after 60 mm evaporation from class A evaporation pan] and factor B was three cultivars of potato [Agria (susceptible), Satina (semi-tolerant) and Ceaser (tolerant to water deficit)]. The first irrigation was general, but the forward irrigation time was determined by below way. Used water amount was calculated according to the collected class A evaporation pan every time and below equation:

$$IW/CPE = 0.8$$

IW = Irrigation water amount irrigation
CPE = Collected evaporation ratio calculated from class A evaporation pan

The amount of irrigation treatments was measured by water meter. The start of irrigation was on base of 30 mm evaporation from class A evaporation pan. Amount of precipitation was measured by udometer and daily evaporation by class A evaporation pan.

Potassium humate sprayed (250 mL ha^{-1}) in the three stages of emergence, before tuberization and during tuberization period. In the growth period and after harvesting, some of characters were measured such as main stem number, plant height, tuber number and weight per plant, total and marketable tuber yield, dry matter percent and marketable tuber number and weight per plant. Mean tuber yield was estimated for each cultivars at each location (environment). Combined analysis of variances were done and comparison of means were done by LSD. G×E interaction was partitioned according to the nonparametric stability analysis of Nassar and Huhn (1987), Thennarasu (1995) and Truberg and Huhn (2000).

RESULTS AND DISCUSSION

Results of Thennarasu's nonparametric stability statistics showed that $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ and $NP_i^{(5)}$ methods, Satina and Caesar cultivars were stable but Agria cultivar was unstable and had the lowest value (Table 1).

Stability parameter $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$ and $NP_i^{(4)}$identified Satina and $NP_i^{(5)}$, Caesar in normal condition, according the $NP_i^{(1)}$, $NP_i^{(2)}$ and $NP_i^{(3)}$, Satina and $NP_i^{(4)}$ and $NP_i^{(5)}$, Caesar in normal with potassium humate condition, $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$ and $NP_i^{(5)}$ to Caesar and Agria in stress with potassium humate condition and $NP_i^{(1)}$, $NP_i^{(2)}$ and $NP_i^{(3)}$, Agria and $NP_i^{(4)}$ and $NP_i^{(5)}$, Caesar and Satina in stress condition as a stable cultivars (Table 2).

Cultivars ranks within environment was shown that Caeser cultivar high ranking, with yield ranks of 3, 2, 3, 3, 3 and 2 across six environments, respectively, prior to Agria cultivar.

$Z_1^{(1)}$ and $Z_2^{(2)}$ sum were 34.08 and 11.24, respectively. Since, both of these statistics were more than the critical value χ^2 0.05, 3 = 7.81, significant differences in rank stability were found among the three cultivars grown in six environments (Table 3).

For normal and normal with potassium humate condition were $Z_1^{(1)}$ and $Z_2^{(2)}$ sum 2.38 and 27.62, respectively. Since both of these statistics were more than the critical value χ^2 0.05, 3 = 7.81, significant differences in rank stability were found among the three cultivars grown in six environments. For stress with potassium humate and stress condition, were $Z_1^{(1)}$ sum 2.38 and 9.146 and $Z_2^{(2)}$ sum 0.608 and 15.10. Since, both of these statistics were less than the critical value χ^2 0.05, 3 = 7.81, no significant differences in rank stability were found among the three cultivars grown in six environments (Table 4).

Figure 1-5 show plots portrayed by mean yield (t ha^{-1}) versus $S_1^{(1)}$ values. Section 1, contains that Caesar cultivar is most stable and well adapted to all environments, that is,

Table 1: Potato cultivars ranking based on corrected tuber yield within environment

Cultivars	Corrected tuber yield (t ha^{-1})	Rank mean	NP_1	NP_2	NP_3	NP_4	NP_5
Caesar	42.60	1.17	0.119	0.110	0.060	0.057	0.040
Satina	34.90	2.83	0.158	0.167	0.091	0.086	0.033
Agria	49.00	1.83	0.002	0.001	0.001	0.001	0.033

Table 2: Potato cultivars ranking based on corrected tuber yield within environment

Irrigation regimes	Cultivars	Corrected tuber yield (t ha^{-1})	Rank mean	$NP_i^{(1)}$	$NP_i^{(2)}$	$NP_i^{(3)}$	$NP_i^{(4)}$	$NP_i^{(5)}$
Normal	Caesar	42.32	1.67	0.055	0.000	0.000	0.000	0.167
	Satina	36.31	2.67	0.224	0.167	0.100	0.164	0.017
	Agria	45.91	1.67	0.055	0.000	0.000	0.000	0.017
Normal with humate	Caesar	45.09	1.67	0.055	0.006	0.000	2.001	0.170
	Satina	39.38	2.67	0.224	0.089	0.015	1.970	0.170
	Agria	42.93	1.67	0.055	0.006	0.000	2.001	0.170
Stress with humate	Caesar	35.88	1.00	0.500	0.383	0.240	1.550	0.006
	Satina	33.04	2.00	0.000	0.000	0.000	2.001	0.006
	Agria	24.91	3.00	0.500	0.382	0.239	1.551	0.052
Stress	Caesar	26.23	1.33	0.225	0.090	0.015	1.970	0.063
	Satina	23.04	1.67	0.055	0.006	0.000	2.001	0.057
	Agria	15.67	3.00	0.500	0.382	0.239	1.551	0.034

Table 3: Estimation and test of nonparametric stability measures for potato cultivars

Cultivars	Tuber yield (t ha^{-1})	Corrected tuber yield (ton ha^{-1})	Rank mean	$S_i^{(1)}$	$Z_i^{(1)}$	$S_i^{(2)}$	$Z_i^{(2)}$
Caesar	42.37	42.37	2.67	0.067	10.109	0.201	2.358
Satina	38.52	38.52	1.17	0.042	17.028	0.377	0.698
Agria	45.59	45.59	2.17	0.092	6.941	0.080	8.184
					ΣZ_i^2=34.08		ΣZ_i^2=11.24
E ($S_i^{(1)}$) = 0.89 Var ($S_i^{(1)}$) = 0.050				E($S_i^{(2)}$) = 0.67		Var($S_i^{(2)}$) = 0.067	
χ^2 sum (Z_1.Z_2) 0.05, 3 = 7.81				χ^2 = 11.52**			

Table 4: Estimation and test of nonparametric stability measures for potato cultivars across environments

Irrigation regimes	Cultivars	Corrected tuber yield (t ha^{-1})	Rank mean	$S_i^{(1)}$	$Z_i^{(1)}$	$S_i^{(2)}$	$Z_i^{(2)}$
Normal	Caesar	42.32	2.33	0.340	0.795	0.054	12.822
	Satina	36.31	1.33	0.340	0.795	0.224	1.974
	Agria	45.91	2.33	0.340	0.795	0.054	12.822
			$\chi^2 = 21.24$**		$\Sigma Z_i^2 = 2.38$		$\Sigma Z_i^2 = 27.62$
Normal with Humate	Caesar	45.09	3.00	0.340	0.795	0.054	12.822
	Satina	39.38	2.00	0.340	0.795	0.224	1.974
	Agria	42.93	1.00	0.340	0.795	0.054	12.822
			$\chi^2 = 21.24$**		$\Sigma Z_i^2 = 2.38$		$\Sigma Z_i^2 = 27.62$
Stress with Humate	Caesar	35.88	3.00	0.340	0.795	0.500	0.304
	Satina	33.04	2.00	0.340	0.795	0.000	0.000
	Agria	24.91	1.00	0.340	0.795	0.500	0.304
			$\chi^2 = 1.06$		$\Sigma Z_i^2 = 2.38$		$\Sigma Z_i^2 = 0.608$
Stress							
	Caesar	26.23	2.67	0.120	4.563	0.224	1.974
	Satina	23.04	2.33	0.120	4.563	0.054	12.822
	Agria	15.67	1.00	1.000	0.020	0.500	0.304
			$\chi^2 = 1.46$		$\Sigma Z_i^2 = 9.146$		$\Sigma Z_i^2 = 15.10$
$E(S_i^{(1)}) = 0.89$	$Var(S_i^{(1)}) = 0.181$		$E(Si^{(2)}) = 0.67$		$Var(Si^{(2)}) = 0.222$		
χ^2 sum $(Z_1.Z_2)$ 0.05, 3 = 7.81							

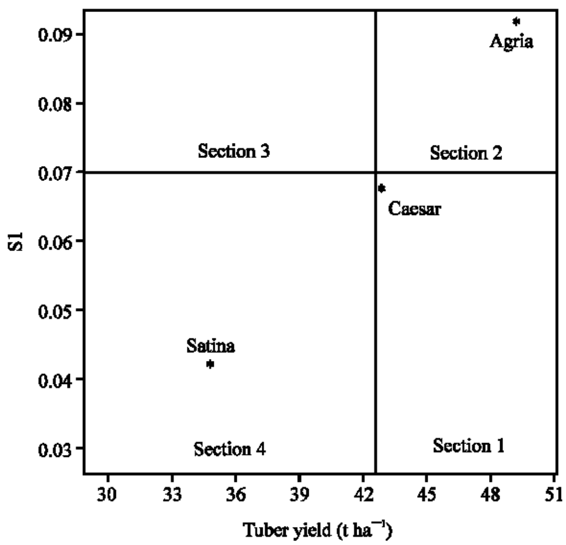

Fig. 1: Biplot of S_1 vs. mean tuber yield for potato cultivars under all of sites

those have general adaptable ability. Agria cultivar appear in section 2, where describes cultivars with increasing sensitivity to environmental change and greater specificity of adaptability to high yielding environments. Section 4 includes Satina cultivar that response greater resistance to environmental fluctuation and therefore increasing specificity of adaptability to low yielding environments (Fig. 1). Caesar and Agria cultivars appeared under normal (Fig. 2) and normal with potassium humate (Fig. 3) conditions, Caesar and Satina cultivars under stress with potassium humate (Fig. 4) and stress (Fig. 5) conditions. Caesar cultivar is most stable and adapted across environments well. Caesar cultivar has the highest mean of rank and yield, while Satina cultivar the lowest. The nonparametric statistics $S_1^{(1)}$ classified genotypes as stable or unstable in a similar fashion. Also, this result reported by Huhn (1996) and Kaya and Taner (2002).

The spearman's rank correlations between each pair of nonparametric stability parameters were calculated and demonstrate a highly significant (p<0.01) rank correlation between tuber yield, $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$, $NP_i^{(5)}$, $S_1^{(1)}$ and $S_2^{(2)}$. The $S_1^{(1)}$ parameter was positively correlated with tuber yield (r = 0.99**). Nassar and Huhn (1987), Sabaghnia *et al.* (2006), Flores *et al.* (1998) and Scapim *et al.* (2000) also found significantly positive correlations.

The $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$, $NP_i^{(5)}$ and $S_2^{(2)}$ had negatively correlated with tuber yield all of them had (r = -0.99**). The correlations were no significant positively between rank-sum and mean yield of cultivars (r = 0.50^{ns}).

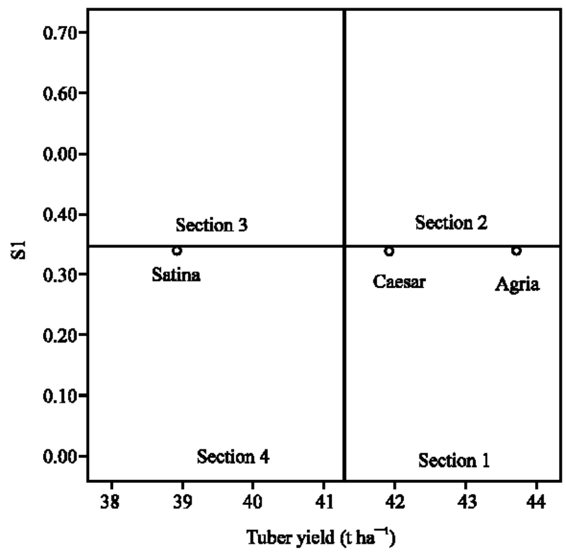

Fig. 2: Biplot of S_1 vs. mean tuber yield for potato cultivars under normal condition

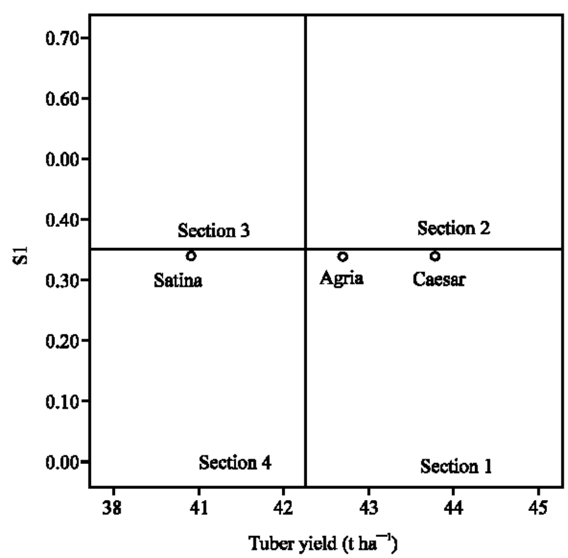

Fig. 3: Biplot of S_1 vs. mean tuber yield for potato cultivars under normal with potassium humate condition

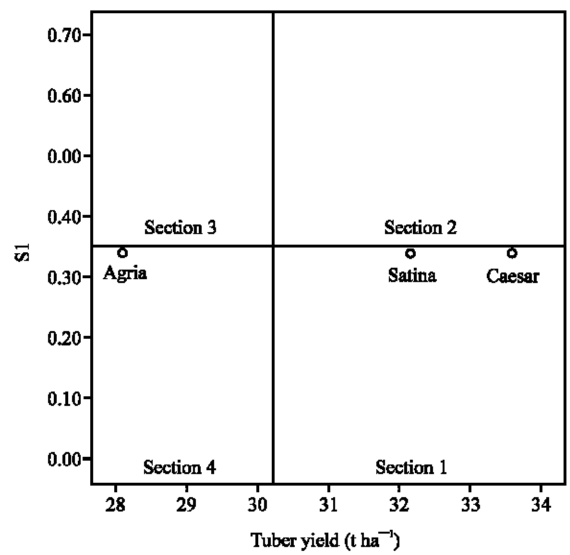

Fig. 4: Biplot of S_1 vs. mean tuber yield for potato cultivars under stress with potassium humate condition

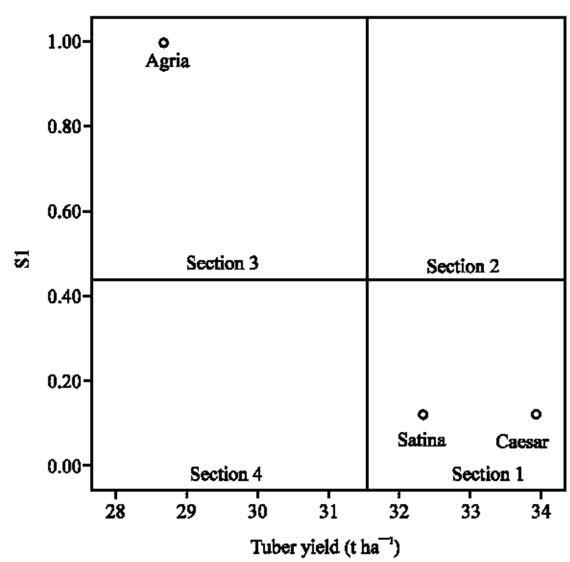

Fig. 5: Biplot of S_1 vs. mean tuber yield for potato cultivars under stress condition

CONCLUSION

According to the $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ and $NP_i^{(5)}$ methods, Satina and Caesar were stable but Agria unstable and had the lowest value. Caesar cultivar is the most stable and adapted across environments well; the highest mean of rank and yield and high ranking under normal, stress with potassium humate and stress conditions. In this study nonparametric statistics $S_1^{(1)}$ selected. This method classifies genotypes as stable or unstable in a similar fashion. The stability parameter $S_1^{(1)}$, was positively and significantly correlated with tuber yield.

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