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Evaluation of Genotype × Environment Interaction of Grapevine Genotypes (*Vitis vinifera* L.) By Non Parametric Method

V. Rasoli[1*], E. Farshadfar[1], and J. Ahmadi[2]

ABSTRACT

To evaluate genotype × environment interaction (GEI) of grapevine, 20 genotypes of grapevines with Russian origin were evaluated at one location in Urmia and four locations in Takestan (two locations under full irrigation and two locations under drought stress). This research was performed in a randomized complete block design with three replications and three vines in each plot, in 2012-2013 season. Data on fruit yield (kg/vine) of the grapevine genotypes grown at different test locations were recorded and subjected to stability analysis by nonparametric methods. Result of the combined ANOVA revealed that variances due to genotypes, environments, and genotype-environment interactions were highly significant. Significant genotypic variance indicated genetic diversity among genotypes yield. The highest $S_i^{(1)}$ and $S_i^{(2)}$ mean absolute rank was observed for genotypes Ramfi TCXA, Apozoski Ramfi, X45 and Anapiski Ramfli, indicating the high instability of these genotypes. Among the individual Z values, it was found that genotypes Ramfi TCXA, Uzbakestan Moscat, Bli Ramfi, Apozoski Ramfi and Anapiski Ramfli were significantly stable relative to the others, of which the $Z_i^{(1)}$ and $Z_i^{(2)}$ values were greater than the table $\chi^2_{(0.05,\ 1)}$(3.84). The genotypes Skieve and Gezgiski Ramfi ranked the first and second, respectively, according to $S_i^{(3)}$, while, according to $S_i^{(6)}$, genotypes Skieve and Uzbakestan Moscat ranked the first and second, respectively. Genotypes Uzbakestan Moscat, Bli Ramfi and Kishmish Ramfi Azos, respectively, had the highest stability and lowest changes in different environments and were recommendable as stable genotypes in different areas. But, it should be noted that yield of these genotypes was moderate. Genotype Muscat had a high yield and moderate stability. As a result, these genotypes (Uzbakestan Moscat, Bli Ramfi, Skieve, Muscat and Kishmish Ramfi Azos) indicated greater resistance to environmental fluctuation and, therefore, increasing specificity of adaptability to low yielding environments.

Keywords: Adaptation, Biplot, Multi-environmental trials, Ranking, Stability Analysis.

INTRODUCTION

Grapevine (Vitis vinifera L.) is one of the most important horticultural crops in the world and Iran. According to the reports of FAO (2012), grapevine cultivated area in the world and Iran is 7,842,366 and 328,082 hectares, respectively. World production of grape is about 68 million tons. Iran, with 3.15 million tons production, is seventh in world ranking. One of the important problems in Iran's vineyards is the instability of the commercial grapevine varieties to environmental variations. This has decreased the country's average yield (14 t/h) compared to global performance (40 t/h). The primary responsibility of grapevine breeders is to evolve and identify superior and stable genotypes. The stable genotype has consistent phenotypic performance over environments. The resultant effect of genotype and environment may not be always independent. The stable genotypes

[1] Department of Plant Breeding, College of Agriculture, Razi University of Kermanshah, Kermanshah, Islamic Republic of Iran.
[*] Corresponding author, email: spiiqv@gmail.com
[2] Imam Khomeini International University, Qazvin, Islamic Republic of Iran.

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can be identified by evaluating them over environments (locations/years). This is subjected to pooled analysis over environments. Interpretation of genotype × environment interaction (GEI) can be aided by statistical modeling. Models can be linear formulations such as joint regression (Yates and Cochran, 1938; Finlay and Wilkinson, 1963; Eberhart and Russell, 1966). Modelling GEI in Multi-environmental trials (MLTs) helps to determine phenotypic stability of genotypes. This concept has been defined in different ways with increasing numbers of stability parameters (Gauch and Zobel, 1996).

Farshadfar (2010) states that there are two major approaches to study G×E interaction and to determine adaptation and stability of genotypes. The most common and first method is parametric, which relies on distributional assumptions about genotypes, environment, and G×E effects. The second method is non-parametric approach. In non-parametric method, as compared to parametric method, no assumptions are needed about the distribution of the analyzed values and homogeneity of variances. Additivity (linearity of effect) is not a necessary requirement (Huehn, 1990) and they reduce the bias caused by outliers. Non-parametric stability measures are expected to be less sensitive to error measurements than parametric estimation and addition or deletion of one or a few observations is not likely to cause or create variation in the estimates as would be the case with stability statistics (Nassar and Huehn, 1987). Therefore, we aimed to evaluate genotypes in various conditions (e.g. drought stress and non-stress) and environments (e.g. Urmia and Takestan), using non-parametric methods so as to introduce the grapevine varieties with stable performance, which would increase the yield, as the main objective of this research.

MATERIALS AND METHODS

In this study, twenty genotypes of grapevines with Russian origin (Table 1) were evaluated in one location in Urmia (with full irrigation) and four locations in Takestan (two locations of under full irrigation and two locations under artificial drought stress) (Table 2). This research was performed in randomized complete block design with three replications and three vines in each plot in growing season of 2012-2013. Data on fruit yield (kg/vine) of

Table 1. Twenty Russian grapevine genotypes.

Code - genotypes	Code - genotypes	Code - genotypes	Code - genotypes
1- Ulskibiser	6- Superan Bulgar	11- Tambuzh Shaki Ramfi	16- Kishmish Ramfi Azos
2- Aligoneh	7- Uzbakestan Moscat	12- Ramfi ezdangara	17- Ukranski Ramfi
3- Ramfi TCXA	8- Bobili Magaracha	13- Muscat	18- Negrod yalon
4- 46X	9- Bli Ramfi	14- Apozoski Ramfi	19- X45
5- Gezgiski Ramfi	10- Skieve	15- Muscat Ruskovi	20- Anapiski Ramfli

Table 2. Some soil, water, and climatological characteristics of the experimental locations.

Location	Geographic position	Soil				Water		Teprature (°C)			Rainfall (mm)	Humedity (%)
		Texture	%N	P mg/kg	K mg/kg	Ec mg/cm	pH	max	min	mean		
Takestan1	36°03'49°40'	Loam	0.06	4.56	300	420	7.2	40	-12	17	290	52
Takestan2	36°21'49°37'	O.L-L	0.05	5.03	270	380	6.9	41	-10	18	270	48
Urmia	54°10'37°35'	Loam	1.03	11.2	425	512	7.9	39	-14	15	365	46

the grapevine genotypes grown at different test locations were recorded and subjected to the stability analysis by nonparametric methods proposed by Huehn (1979) and Nassar and Huehn (1987). They were based on ranks of genotypes within environment. Genotypes with similar ranking across environments were classified as the most stable.

Huehn (1979) and Nassar and Huehn (1987) proposed the following four non-parametric measures of phenotypic stability.

1) Mean of the Absolute Rank Differences ($S_i^{(1)}$) of a Genotype

$$S_i^{(1)} = \frac{2\sum_{j=1}^{q-1}\sum_{j'=j+1}^{q}|r_{ij} - r_{ij'}|}{q(q-1)} \quad (1)$$

Where,

$\bar{r}_{ij}$= mean of ranks over environments.

r_{ij}= rank of genotypes in each environment based on $(Y_{ij} - \bar{Y}_{i.} + \bar{Y}_{..})$.

q= number of environments

Ranks are assigned from the lowest to highest.

2) Variance Among the Ranks over the q Environments ($S_i^{(2)}$)

$$S_i^{(2)} = \frac{\sum_{j-1}^{q}(r_{ij} - r_{i.})^2}{q(q-1)} \quad (2)$$

Where,

$S_i^{(1)}$ and $S_i^{(2)}$ have been investigated by Nassar and Huehn (1987). Significance tests based on the normal distribution were developed for these two nonparametric measures. At the first $S^{(m)}$ statistic was estimated as below.

$$S^{(m)} = \sum_{i=1}^{k} Z_i^{(m)} = \sum_{i=1}^{k} \frac{|(S_i^{(m)} - E(S_i^{(m)}))^2|}{Var(S_i^m)} \quad (3)$$

Where, m= 1, 2

$E(S_i^{(1)}) = (p^2 - 1)/3p$

$E(S_i^{(2)}) = (p^2 - 1)/12$

$Var(S_i^{(1)}) = (p^2 - 1)[(p^2 - 4)(q + 3) + 30]/45p^2 q(q-1)$

$Var(S_i^{(2)}) = (p^2 - 1)[2(p^2 - 4)(q - 3) + 5(p^2 - 1)]/360\, q(q-1)$

p= number of genotypes and q= number of environments

The statistic Z_i may be approximated by a chi-square distribution with 1 degree of freedom. Also, $S^{(m)}$ has chi-square distribution approximately with 1 degree of freedom.

Under the null hypothesis that all genotypes are equally stable, the mean $E(S_i^{(m)})$ and variances $Var(S_i^{(m)})$ may be computed from the discrete uniform distribution (1,2,…,p).

3) Mean of the Absolute Rank Differences ($S_i^{(3)}$) of a Genotype

$$S_i^{(3)} = \frac{\sum_{j=1}^{q}|r_{ij} - \bar{r}_{i.}|}{\bar{r}_{i.}} \quad (4)$$

Where, $\bar{r}_{i.}$ =mean of ranks over environments

r_{ij}= rank of i^th^ genotypes in each j^th^ environment based on mean yield

Ranks are assigned from the lowest to highest

q= number of environments

4) Variance among the Ranks over the q Environments ($S_i^{(6)}$)

$$S_i^{(6)} = \frac{\sum_{j=1}^{q}(r_{ij} - \bar{r}_{i.})^2}{\bar{r}_{i.}} \quad (5)$$

RESULTS

Yield data of 20 grapevine genotypes grown at five Takestan and Urmia locations during 2012-2013 were collected. Descriptive diagram of yield indicated the existence of genotype × environment interactions and high variability for yield over different genotypes and environments (Figure 1). The genotype × environment interactions (GEI) of yield for genotypes 46X, Superan Bulgar, Muscat, Apozoski Ramfi and Anapiski Ramfli were higher than other genotypes in different environments, while GEI of yield for genotypes Aligoneh, Ramfi TCXA, Bobili

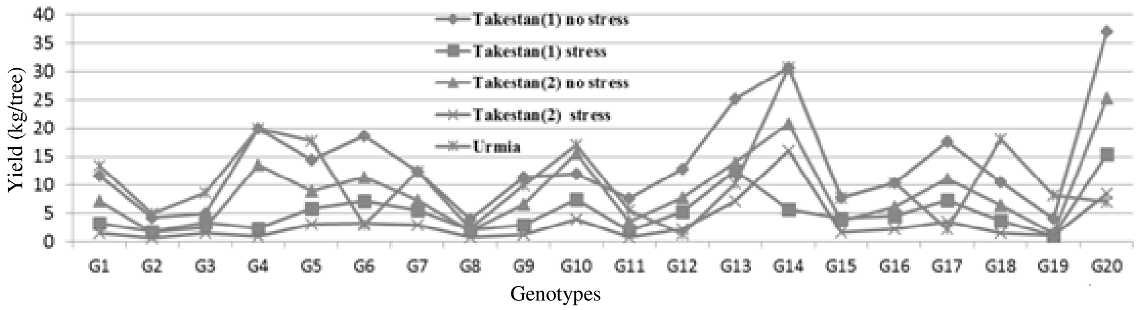

Figure 1. Descriptive diagram of yield of genotype × environment interactions

Magaracha, Tambuzh Shaki Ramfi, Muscat Ruskovi and X45 were lower than other genotypes.

These data were subjected to analysis of variance (ANOVA) for individual location. The ANOVA for individual locations indicated that the variance for genotypes was found highly significant ($p<0.01$) in all the locations. This suggests the presence of genetic variability among the genotypes under study at most of the locations (Table 3). Also, combined ANOVA of yield of 20 genotypes over different environment was done and indicated that effects of genotypes and GEI were significant (Table 4). Means comparison yield of genotypes was done by Duncan's Multiple Range Test (DMRT) in $\alpha=0.05$ for five environments separately (Table 5) and combined means comparison yield (Table 6), which indicated that genotypes were grouped in 10 groups. Genotypes Apozoski Ramfi and Anapiski Ramfli (with 18.196 and 18.676 kg/vine, respectively) had the higher yield than other genotypes. Also, Genotype Bobili Magaracha with 2.227 kg/vine had the lowest yield compared to other genotypes (Table 6).

The parametric stability methods have good properties under certain statistical assumption like normal distribution of error and interaction effects, however, they may not perform well if these assumptions are violated (Huehn, 1990). Parametric tests for significance of variance and variance related measures could be very sensitive to the underlying assumptions. Thus, it is wise to search for alternative approaches that are more robust to departures from common assumption, such as non-parametric

Table 3. Analysis of variance for individual locations.

Source of variation	Degree of freedom	E1	E2	E3	E4	E5
Replication	2	87.96	2.260	55.90	1.188	17.793
Genotype	19	251.29**	38.756**	128.25**	12.987**	160.911**
Error	38	39.13	5.626	22.25	2.477	7.614

**: significant difference at $\alpha=0.01$

Table 4. Combined analysis of variance for all locations.

Source of variation	Degree of freedom	Sum of square	Mean of square	F. value	F. probability
Environment	4	5153.46	1288.37	39.02**	<.001
Environment/replication	10	330.21	33.02	2.14	
Genotype	19	6518.26	343.07	22.25**	<.001
Genotype× environment	76	4733.40	62.28	4.04**	<.001
Residual	190	2929.53	15.42		
Total	299	19664.86			

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Table 5. Duncan's Multiple Range Test (DMRT) for comparison of mean yields of genotypes in five environments (α=0.05).

Genotype	Takestan(1) no stress		Takestan(1) stress		Takestan(2) no stress		Takestan(2) stress		Urmia	
Ulskibiser	11.61	efg	3.202	bcd	7.188	cdefgh	1.441	bc	13.37	cde
Aligoneh	4.34	g	1.76	cd	1.684	h	0.594	c	5.04	ghij
Ramfi TCXA	5.01	g	3.421	bcd	2.488	fgh	1.499	bc	8.56	efg
46X	19.91	bcde	2.335	cd	13.542	bcde	0.888	bc	19.91	b
Gezgiski Ramfi	14.49	cdefg	5.863	bc	8.898	cdefgh	3.111	bc	17.81	bc
Superan Bulgar	18.63	cdef	7.143	b	11.326	cdef	3.209	bc	2.98	hij
Uzbakestan Moscat	12.33	defg	5.647	bcd	7.334	cdefgh	2.933	bc	12.33	def
Bobili Magaracha	3.95	g	2.082	cd	1.938	gh	0.755	c	2.41	ij
Bli Ramfi	11.37	efg	3.032	bcd	6.639	defgh	1.149	bc	9.95	efg
Skieve	23.7	bcd	7.424	b	15.55	bcd	3.963	b	16.97	bcd
Tambuzh Shaki Ramfi	7.55	fg	1.951	cd	3.612	fgh	0.732	c	5.52	ghij
Ramfi ezdangara	12.82	defg	5.223	bcd	7.764	cdefgh	2.24	bc	1.38	j
Muscat	25.14	bc	12.486	a	15.923	bc	7.169	a	10.29	efg
Apozoski Ramfi	30.7	ab	5.706	bcd	20.746	ab	3.135	bc	30.7	a
Muscat Ruskovi	7.75	efg	4.123	bcd	3.682	fgh	1.729	bc	7.75	fgh
Kishmish Ramfi Azos	10.31	efg	4.555	bcd	6.099	efgh	2.298	bc	10.31	efg
Ukranski Ramfi	17.69	cdef	7.296	b	11.046	cdefg	3.478	bc	2.17	ij
Negrod yalon	10.49	efg	3.693	bcd	6.516	defgh	1.541	bc	18.11	bc
X45	4.16	g	1.069	d	1.449	h	1.024	bc	8.24	efg
Anapiski Ramfli	37.09	a	15.461	a	25.291	a	8.486	a	7.05	ghi

measures (Nassar and Huehn 1987 and Huehn and Nassar, 1989). Huehn (1979) and Nassar and Huehn (1987) proposed four non-parametric measures of phenotypic stability.

1. Mean of the Absolute Rank Differences $S_i^{(1)}$ of a Genotype and Variance among the Ranks $S_i^{(2)}$ over the Environments

Non-parametric methods are based on the ranks of the genotypes across locations. They give equal weight to each location or environment. Genotypes with less change in ranks are expected to be more stable. The mean absolute rank difference $S_i^{(1)}$ estimates all possible pair-wise rank difference across locations for each genotypes. The $S_i^{(2)}$ estimates are simply the variance of ranks for each genotypes over environments. For the variance of ranks $S_i^{(2)}$, smaller estimates may indicate relative stability. Often, $S_i^{(2)}$ has less power for detecting stability than $S_i^{(1)}$. The $S_i^{(1)}$ may lose power when genotypes are similar in their interactions with the environments. Two rank stability measures proposed by Huehn (1979) were worked out and expressed as $S_i^{(1)}$ and $S_i^{(2)}$ and are presented in Table 6. The genotypes Uzbakestan Moscat, Bli Ramfi, Tambuzh Shaki Ramfi and Kishmish Ramfi Azos had the lowest value of $S_i^{(1)}$ and $S_i^{(2)}$ and ranked 12th, 8th, 4th and 9th for yield, respectively. Genotypes Uzbakestan Moscat and X45 had higher yield than genotypes Bli Ramfi and Tambuzh Shaki Ramfi, thus, Genotypes Uzbakestan Moscat and X45 were stable. The highest $S_i^{(1)}$ and $S_i^{(2)}$ mean absolute rank was observed for genotypes Ramfi TCXA, Apozoski Ramfi, X45, and Anapiski Ramfli indicating to be highly unstable genotypes.

For each genotype, $Z_i^{(1)}$ and $Z_i^{(2)}$ values were estimated based on ranks of the corrected data and summed over genotypes to obtain Z values (Table 6).

$\Sigma Z_i^{(1)}$ (38.27) and $\Sigma Z_i^{(2)}$ (66.17) are distributed as χ^2 and were more than the critical value of $\chi^2_{(0.05,20)}$ (31.41), which indicated the significant differences among the ranks of stability of the twenty genotypes. Among the individual Z values, it was found that genotypes Ramfi TCXA, Uzbakestan Moscat, Bli Ramfi, Apozoski Ramfi and Anapiski Ramfli were

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Table 6. Ranks of 20 grapevine genotypes after yield data from 5 environments were analyzed for G×E interaction and stability using nonparametric methods.

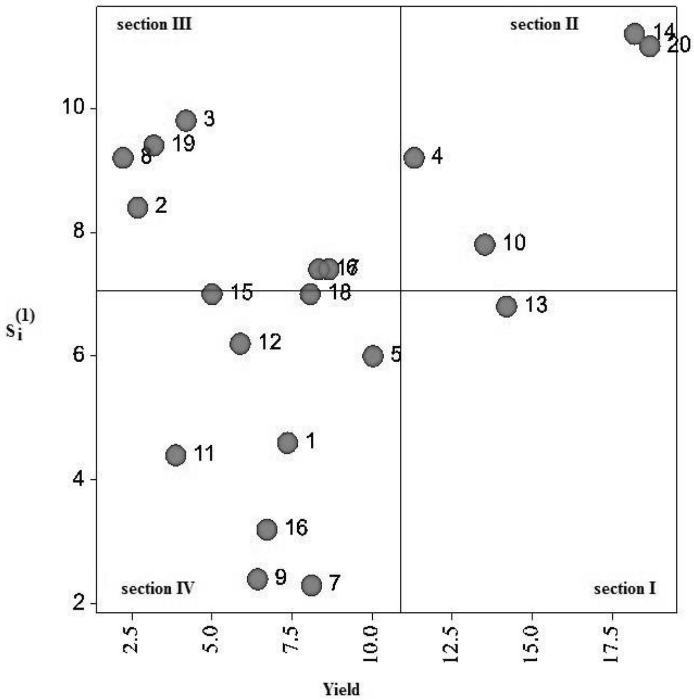
Code	Genotypes	Means with (DMRT) [a]	Rank of means	$S_i^{(1)}$	Rank of $S_i^{(1)}$	$S_i^{(2)}$	Rank of $S_i^{(2)}$	$S_i^{(3)}$	Rank of $S_i^{(3)}$	$S_i^{(6)}$	Rank of $S_i^{(6)}$	$Z_i^{(1)}$	$Z_i^{(2)}$
1	Ulskibiser	7.364 defg	10	4.6	5	14.2	5	1.14	8	4.37	13	1.26	1.84
2	Aligoneh	2.684 ij	2	8.4	14	46.3	14	2.15	18	3.54	11	0.83	0.85
3	Ramfi TCXA	4.195ghij	5	9.8	18	68.3	18	1.65	15	4.24	12	2.75	6.18*
4	46X	11.316bc	16	9.2	15.5	60.8	17	2.50	19	16.17	20	1.79	3.81
5	Gezgiski Ramfi	10.034cd	15	6.0	6	27.2	6	0.44	2	0.78	3	0.14	0.19
6	Superan Bulgar	8.656cde	14	7.4	11.5	36.5	10	1.39	12	8.09	16	0.14	0.05
7	Uzbakestan Moscat	8.114def	12	2.3	1	5.2	2	0.45	3	0.58	2	5.53*	3.98*
8	Bobili Magaracha	2.227j	1	9.2	15.5	59.2	16	1.29	11	1.71	5	1.79	3.38
9	Bli Ramfi	6.428efgh	8	2.4	2	4.3	1	1.07	7	2.29	8	5.28*	4.24*
10	Skieve	13.522b	17	7.8	13	39.7	11	0.19	1	0.16	1	0.35	0.21
11	Tambuzh Shaki Ramfi	3.874hij	4	4.4	4	12.8	4	1.62	14	2.57	9	1.51	2.12
12	Ramfi ezdangara	5.886efghi	7	6.2	7	29.7	7	1.79	17	9.71	17	0.07	0.07
13	Muscat	14.202b	18	6.8	8	32.2	9	0.60	4	2.02	7	0.00	0.01
14	Apozoski Ramfi	18.196a	19	11.2	20	94.8	20	0.67	5	1.68	4	5.79*	19.1*
15	Muscat Ruskovi	5.005fghij	6	7.0	9.5	31.7	8	1.00	6	2.00	6	0.03	0.01
16	Kishmish Ramfi Azos	6.715efgh	9	3.2	3	6.5	3	1.20	9.5	3.20	10	3.50	3.62
17	Ukranski Ramfi	8.335cde	13	7.4	11.5	41.3	12	1.69	16	12.09	18	0.14	0.32
18	Negrod yalon	8.069def	11	7.0	9.5	42.8	13	1.46	13	7.04	14	0.03	0.46
19	X45	3.189ij	3	9.4	17	58.3	15	3.78	20	13.11	19	2.08	3.15
20	Anapiski Ramfli	18.676a	20	11.0	19	83.3	19	1.20	9.5	7.77	15	5.28*	12.6*

$E(S_i^{(1)})= 6.7$ $E(S_i^{(2)})= 33.3$ $Var(S_i^{(1)})= 3.5$ $Var(S_i^{(2)})= 198.3$ $\Sigma Z_i^{(1)}= 38.27$ $\Sigma Z_i^{(2)}= 66.17$

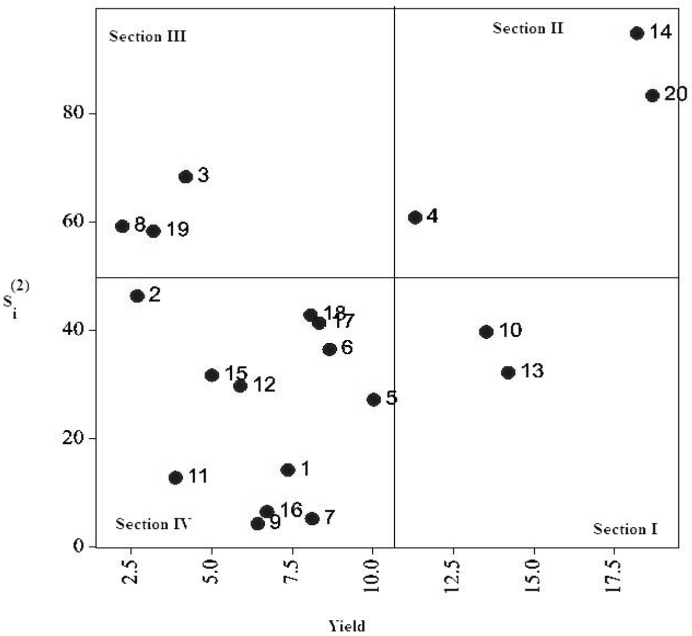
[a] Duncan's Multiple Range Test.

significantly stable relative to others, their $Z_i^{(1)}$ and $Z_i^{(2)}$ values were greater than the table $\chi^2_{(0.05, 1)}$(3.84).

Figures 2(a-b) represent plots portrayed by mean yield (kg/vine) Vs. $S_i^{(1)}$ and $S_i^{(2)}$ values. Mean $S_i^{(1)}$ and $S_i^{(2)}$ values and grand mean yield divide both figures into four sections. Section 1 includes genotypes that have high grain yield and small $S_i^{(1)}$ and $S_i^{(2)}$ values and can be considered as stable and well adapted to all environment. Section 2 contains genotypes that possess high yield



(a)



(b)

Figure 2. BiPlot of (a) $S_i^{(1)}$ *vs.* (b) $S_i^{(2)}$ *vs.*, mean yield for grapevine genotypes over different environments.

and large $S_i^{(1)}$ and $S_i^{(2)}$ values, with increasing sensitivity to environmental changes and greater specificity of adaptability to high yielding environments. Section 3 referring poorly adapted genotypes to all environments (Fig. 2 a, b). Section 4 exhibits that genotypes of low yielding and small $S_i^{(1)}$ and $S_i^{(2)}$ values are indicative of resistance to environmental fluctuation and, therefore, increasing specificity of adaptability to low yielding environments. According to the results, genotype Muscat was located in section I and had high yield and median stability; also, genotypes Uzbakestan Moscat, Bli Ramfi and Kishmish Ramfi Azos were located in section IV and had the highest stability and median yield.

2. Mean of the Absolute Rank Differences $S_i^{(3)}$ of a Genotypes and Variance among the Ranks $S_i^{(6)}$ over the Environments.

The Y_{ij} values must not be corrected for the genotypic effects before ranking because information about trait level would be lost. Huehn (1979) proposed two non-parametric statistics for the simultaneous estimation of performance and stability which are $S_i^{(3)}$ and $S_i^{(6)}$. These statistics measure stability in units of the mean rank of the $_i^{th}$ genotype using $S_i^{(3)}$, the differences between rank and mean rank are weighted with themselves avoiding the possibility that a lot of smaller rank differences may lead to the same $S_i^{(3)}$ value as a few larger differences.

These $S_i^{(3)}$ and $S_i^{(6)}$ non-parametric measures were worked out by using the ranks which were assigned to genotypes on the basis of the original mean data within environment and are presented in Table 3. The results of $S_i^{(3)}$ and $S_i^{(6)}$ indicated that the genotypes Skieve and Gezgiski Ramfi ranked first and second, respectively, according to $S_i^{(3)}$ and genotypes Skieve and Uzbakestan Moscat ranked first and second, respectively, according to $S_i^{(6)}$. Genotypes Skieve, Gezgiski Ramfi, and Uzbakestan Moscat occupied 17th, 15th, and 12th position in mean yield, therefore, these genotypes were found to be stable and adapted to all environments. According to $S_i^{(3)}$ and $S_i^{(6)}$, genotypes Anapiski Ramfli and 46X were found to be most unstable.

DISCUSSION

Huehn (1990) used three non-parametric measures, namely, $S_i^{(1)}$, $S_i^{(2)}$ and $S_i^{(3)}$ for phenotypic stability of winter wheat grain yield in Germany. He concluded that for simultaneous consideration of both stability and yield, $S_i^{(3)}$ can be applied and used on original (Uncorrected yield) data, because correction eliminates the genotypic effects from the data. Sabaghnia *et al*. (2006) worked out all four non-parametric stability measures for lentil genotypes in Iran and interpreted a similar type of results. Also, $S_i^{(3)}$ measure was used to find the stable cowpea (*Vigna unguiculata* L.) genotypes by Aremu *et al*. (2007).

Sivčev *et al* (2011) evaluated effect of the genotype x environmental interaction on phenotype variation of the bunch weight in white wine grapevine varieties of Danube region in the central Serbia by factor and cluster analysis methods. They indicated that yield and berries sugar content of the varieties were affected by GEI. They also introduced stable varieties (Dymiat and Kladovka) for all conditions by this method.

Serra (2013) showed that there was a difference in root density and drought stress responses attributed by genetic differences of grapevine rootstocks and GEI. To understand the effect that rootstock has on drought responses, it is important to consider the exogenous factors and the GEI (Serra, 2013). It has been shown that the distribution of the root system of a vine depends on the interaction of the rootstock genotype with the soil texture and bulk density, water and nitrogen availability, soil salinity, vine spacing, and climatic conditions (Koundouras, 2008).

Cooley (2012) investigated GEI during the early stages of grapevine reproduction and the physiological processes determining fruitfulness and yield in grapevines. Temperature effects may be due to changes in carbohydrate partitioning and/or gene expression pathways. The spatial expression of known key flowering genes *VvTFL1*, *VvLFY* and *VvFT* were explored. Correlation of the genes *VvLFY* and *VvFT* was undetermined and likely reflects the complexity of the fruitfulness/environmental interaction. Over twenty new genes involved in grapevine flowering were identified by gene expression studies, with four of considerable interest for further study. Temperature has a significant and complicated association with optimal bud fruitfulness and the findings reported here suggest that complexity in gene expression of known and new flowering genes reflect these associations.

Mohammadi *et al.* (2007) evaluated GEI on grain yield data of 20 winter wheat genotypes and their stability by different nonparametric tests. Combined ANOVA across environments, principal component analysis (PCA) and correlation analysis of nonparametric stability statistics were used in this study. Genotypes with low and high stability and yield were determined.

Parmar *et al.* (2012) surveyed the adaptability of promising rice genotypes in different agro-ecological regions of Gujarat state to varying climatic and soil conditions. This research was carried out at 4 different locations. Yield data were analyzed by using pooled ANOVA and non-parametric methods. Genotypes with low and high adaptability were determined for each location and GEI of rice genotypes was interpreted by these methods. Also, this method was used in stability measurements of 20 genotypes of durum wheat by Sabaghnia *et al*. (2012).

Farshadfar *et al.* (2012) indicated that non-parametric method was efficient in determination of chromosomal localization of QTLs controlling GEI in wheat substitution lines. They reported that most of the quantitative trait loci (QTLs) involved in controlling phenotypic stability in wheat were located on the chromosomes 2A, 3A, and 4A in A genome and 3D and 5D in D genome.

According to the final result of this study, genotypes Uzbakestan Moscat, Bli Ramfi and Kishmish Ramfi Azos had the highest stability and lowest changes in different environments, respectively, and were recommendable as stable genotypes in different areas. But, it should be noted that yield of these genotypes was moderate. Genotype Muscat had high yield and moderate stability. When there is an interaction between genotype and environment, effects of genotype and environment statistics are non-additive. This means that differences between genotypes depends on the environmental changes. The effects of genotype and environment may lead to a different ranking of genotypes in different environments. In many applied studies, the researcher will not know whether there is an interaction between genotype and environment or not. The main objective of vine breeders is the rank of various genotypes in different environments and change of their rank. The breeder is actually looking for an answer to this question that whether the best genotype in one environment is also the best in another environment or not. This means that the relative characterization and comparison of genotypes (their ranks) is more important than comparison of their absolute values. Therefore, information of ranking is used for quantitative explanation of these relations.

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ارزیابی اثر متقابل ژنوتیپ × محیط ژنوتیپ‌های انگور (*Vitis vinifera* L.) به روش ناپارامتری

و. رسولی، ع. فرشادفر، و ج. احمدی

چکیده

به منظور بررسی اثر متقابل ژنوتیپ × محیط ژنوتیپ‌های انگور (GEI)، ۲۰ ژنوتیپ انگور با منشاء کشور روسیه در یک مکاندر ارومیه و چهار مکان در تاکستان (دو مکان تحت آبیاری کامل و دو مکان تحت استرس خشکی) مورد ارزیابی قرار گرفت. این آزمایش در قالب طرح بلوک‌های کامل تصادفی با سه تکرار و سه بوته در هر واحد آزمایشی در سال زراعی ۹۲-۱۳۹۱انجام شد. عملکرد انگور (کیلوگرم در بوته) هر ژنوتیپ در هر محل یادداشت شده و به عنوان داده آزمایشی در تجزیه پایداری به روش ناپارامتری استفاده گردید. نتایج تجزیه واریانس مرکب نشان داد که واریانس ژنوتیپی، محیطی و اثر متقابل ژنوتیپ- محیط معنی دار بود. معنی دار بودن واریانس ژنوتیپی نشان دهنده تنوع ژنتیکی بین عملکرد ژنوتیپ‌ها بود. بالاترین میانگین قدر مطلق رتبه $S_i^{(1)}$و $S_i^{(2)}$در ژنوتیپ‌های Ramfi TCXA، Apozoski Ramfi، X45 و Anapiski Ramfli مشاهده شد که نشان دهنده ناپایداری بالای این ژنوتیپ‌ها بود. در میان مقادیر Z ژنوتیپ‌ها، نشان داد که ژنوتیپ‌های Ramfi TCXA، Uzbakestan Moscat، Bli Ramfi، Aponzoski Ramfi و Anapiski Ramfli به طور معنی داری پایدارتر از سایر ژنوتیپ‌ها بود که مقادیر $Z_i^{(1)}$ و $Z_i^{(2)}$آنها بالاتر از سایر ژنوتیپ‌ها $\chi^2_{(0.05,\ 1)}$ (۳/۸۴) بود. نتایج $S_i^{(3)}$ و $S_i^{(6)}$ نشان داد که ژنوتیپ‌های Skieve و Gezgiski Ramfi به ترتیب در رتبه اول و دوم بر اساس $S_i^{(3)}$ و ژنوتیپ‌های Skieve و Uzbakestan Moscat به ترتیب در رتبه اول و دوم بر اساس $S_i^{(6)}$قرار گرفتند. ژنوتیپ‌های Uzbakestan Moscat، Bli Ramfi و Kishmish Ramfi Azos به ترتیب دارای پایداری بالا و تغییرات کمتر در محیط‌های مختلف بوده و به عنوان ژنوتیپ‌های پایدار در مناطق مختلف قابل توصیه بودند. اما باید به این نکته توجه کرد که عملکرد این ژنوتیپ‌ها در حد متوسط بود. ژنوتیپ Muscat دارای عملکرد بالا ولی پایداری متوسط بود. در نتیجه این ژنوتیپ‌ها (Uzbakestan Moscat، Bli Ramfi، Skieve، Muscat و Kishmish Ramfi Azos) مقاومت بالاتری به نوسانات محیطی نشان داده و بنابراین قابلیت سازگاری بالاتری به محیط‌های با عملکرد پایین دارند.

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