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EVALUATION OF GRAIN YIELD STABILITY OF SUPERIOR TRITICALE GENOTYPES

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Abstract

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Triticale is a synthetic crop developed by crossing between wheat and rye which had shown suitable traits such as high yielding of forage and grains, it performs better under harsh environment in comparison with wheat and barley. In order to study of stability of superior triticale lines, this investigation was conducted at two stations in two growing seasons. This study was assigned in randomized complete block design with 3 replications. Each experiment consists of 18 promising lines and cultivars of triticale in addition of two checks of triticale: ET-79-17 and Sanabad. The grain yield of ET-79-17 line were higher than others. The results of rank analysis showed that among studied genotypes, first control had best rank and after it ranking of lines number 6, 12 and 20 were better than others, also minimum environmental coefficient variation was related to lines number 3, 8 and 19. Stability analysis carried out with stability variance of Shukla, Roemer's environmental variances, Wricke's equivalence, Finlay and Wilkinson method, Minimum amounts of Lin and Binns variance. In identification of stable lines Wricke's equivalence and stability variance of Shukla was similar together. Roemer's environmental variances had positive and significant correlation at 1% probability level with variance of Shukla, Wricke's equivalence and Lin and Binns variance. Finally, according to different stability parameters it was obvious that lines number 6, 12 and 20 along with ET-79-17 line were more stable than others, so these lines were selected in final.

Key words: triticale, promising lines, yield stability, yield comparison
Abbreviations: Standard Deviation of Rank (SDR), Environmental coefficient of variation (CV), Average Ranking (R_i), Roemer's environmental variance (S_i^2), Shukla stability variance (σ_i^2), Wrick's equivalence (w_i^2), Stability variance of Finlay and Wilkinson (b_i), Spatial variance of Lin and Binns (LBV)

Introduction

Triticale, the first successful human-made cereal that is produced from a cross between wheat and rye in 1875 (Dumbrava et al., 2014). Since then, the evolution of this plant, be interested for many scientists. According to many contemporary scholars, triticale must be the best properties of both parents, the quality of wheat for marketing and with rye resistance to adapt to difficult soil conditions, drought tolerance, cold tolerance and disease and low food demand (Dumbrava et al., 2014).

Today, triticale is concerned as a commercial crop with vast potential for nutrition of human and animal. In compared with wheat, with better dry matter and grain yield, triticale considered as a feed source for cattle (Ghodsi, 2009). In the last three decades, area of triticale cultivation is reached

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more than 4.2 million hectares and according to available statistics, more than 120 varieties are grown in 35 countries (Chapman et al., 2005).

CIMMYT triticale breeding program began in 1965 and was achieved significant progress. One of the first developments were introduction lines with insensitive to photoperiod (Zillinsky and Borlaug, 1971). A frequent goal of plant breeding for areas with limited resources for agricultural inputs is to produce varieties with higher average yield across diverse environments. Genotype by environment (G x E) interactions, however, frequently interfere with the selection of widely adapted genotypes (Ceccarelli, 1994).

Generally, a small fraction of genotype × environment is related to known environmental factors and a major part of which is un-described value in experimental analysis of yield, In terms of yield stability, depending on the desired goals of stability, defined two completely different concepts of sustainability as static and dynamic concept (Becker et al., 2001). In breeding progress, genotypes were examined in varied environment such as different location and years for best suggestion of genotypes with best stability and performance (Farokhzade et al., 2013). To investigate the stability data presented is different statistical methods (Fallahi et al., 2007). All of these methods are presented by different researchers and compared the diagnostic performance stable varieties and have been identified the weaknesses or strengths. But in any case there is no definitive method is quite acceptable (Vahabzadeh et al., 2006).

In this study yield stability of number of triticale lines that obtained from four different environments were analyzed with greater performance, using parameters SDR, environmental coefficient of variation, average ranking, environmental vari-

Table 1
Pedigree and origin of triticale genotypes that used in this experiment

No.	Pedigree	Origin
1	ET-79-17 (Control 1)	CIMMYT
2	Sanabad (Control 2)	CIMMYT
3	DAHBI_6/3/ARDI_1/TOPO 1419//ERIZO_9/4/SONNI_3	CIMMYT
4	T1502_WG/MOLOC_4//RHINO_3/BULL_1-1/3/FAHAD_5*2/RHINO 1R.1D 5+10 5D´5B´	CIMMYT
5	T1502_WG/MOLOC_4//RHINO_3/BULL_1-1/3/POLLMER_3/FOCA_2-1	CIMMYT
6	BAT*2/BCN//CAAL/3/ERIZO_7/BAGAL_2//FARAS_1	CIMMYT
7	DAHBI_6/3/ARDI_1/TOPO 1419//ERIZO_9/5/6TA876/6TB164//PND-T/RHM/3/…	CIMMYT
8	DAHBI/COATI_1//ASAD/FAHAD_1	CIMMYT
9	DAHBI_6/3/ARDI_1/TOPO 1419//ERIZO_9/4/2*SONNI_3	CIMMYT
10	DAHBI_6/3/ARDI_1/TOPO 1419//ERIZO_9/4/DAGRO/IBEX//CIVET#2/5/FAHAD_5/…	CIMMYT
11	AR/SNP6//TARASCA 87_3/C,S10/3/URON_5/TATU_1/4/POLLMER_4//…	CIMMYT
12	AR/SNP6//TARASCA 87_3/C,S10/3/URON_5/TATU_1/5/PRESTO//2*TESMO_1/…	CIMMYT
13	LIRON_2/5/DIS B5/3/SPHD/PVN//YOGUI_6/4/…	CIMMYT
14	T1502_WG/MOLOC_4//RHINO_3/BULL_1-1/3/…	CIMMYT
15	STIER_22-1/NIMIR_3/6/IA-T/M2A//PI/3/BGL/5/…	CIMMYT
16	POLLMER_2.2.1*2//FARAS/CMH84.4414	CIMMYT
17	804/BAT/3/MUSX/LYNX//STIER_12-3/4/…	CIMMYT
18	DAHBI_6/3/ARDI_1/TOPO1419//ERIZO_9/4/…	CIMMYT
19	POLLMER_2.3.1/3/PASSI_3-2//GNU*2/SPB	CIMMYT
20	DAHBI/COATI_1//ASAD/FAHAD_1	CIMMYT

ance of Roemer (Roemer, 1917), Shukla's stability variance (Shukla, 1972), Wricke's equivalence (Wricke, 1962), Stability variance of Finlay and Wilkinson (Finlay and Wilkinson, 1963) and the spatial variance of Lin and Binns (Lin and Binns, 1991) to determine stable genotypes. The aim of this study is to obtain a variety which performs well in nearly all environments. The adaptive response of a variety is assessed with respect to other genotypes and tends to undergo modification when better-performing germplasm becomes available.

Materials and Methods

This experiment were carried out in randomized complete block design with three replications for two years in two research stations with 18 promising lines and two control lines of triticale (ET-79-17 and Sanabad). Pedigree of these genotypes was executed in Table 1.

Total area planted for each treatment equal 6 × 1.2 = 7.2 m^2 and each genotype were planted on the 6 line to a distance of 20 cm and a length of 6 meters. Area harvested after the removal of half a meter from the beginning and end of each plot were 1.2 × 5 = 6 m^2. Seeding density for each genotypes were 450 plants per m^2.

The amount of fertilizer was based on soil analysis. Seedbed preparation, i.e. plowing, leveling and disc harrow were carried out according planting instructions. After fertilizer was used, created the Faros. Planting date is the first half of November in both locations and both years. Phosphorus and potassium fertilizer and two-third of nitrogen fertilizer get sprinkled at planting time and the remaining one-third of nitrogen in two phases beginning of the end of tillering and heading be spent as top dressing.

Planting of each genotypes was done with seed drill for cereal experiment. For weed control was used herbicides as 2-4- D (1.5 liter/ha) and Granstar (20 gr/ha) at the late tillering stage. Harvest were conducted by combines for experimental cereals and grain yield were measured separately for each treatment. For selection of sustainable genotypes, statistical analysis was performed as follows:

A) Analysis of variance on grain yield in every region and every year.

B) Test the uniformity of experimental error variance (Bartlett) and analysis of variance on results of stations to determine the main and interaction effects of cultivar and region.

C) Analysis of variance on the outcomes of all regions in different years in order to investigate the interactions between cultivars, regional and years. Also, due to the expected mean square and on the basis of Karmr et al., (1989) was the definition of experimental error for each source.

D) Evaluation of yield stability using eight parameters including 1 – Standard Deviation of Rank (SDR), 2 – Environmental coefficient of variation (CV), 3 – Average Ranking (Ri), 4 – Roemer's environmental variance (S_i^2), 5 – Shukla stability variance (σ_i^2), 6 – Wrick's equivalence (w_i^2), 7 – Stability variance of Finlay and Wilkinson (b_i) and 8 – Spatial variance of Lin and Binns (LBV).

To calculate the stability parameters were used Shukla (σ_i^2), Wrick's equivalence (w_i^2), Finlay and Wilkinson's stability variance (b_i), Roemer's environmental variance (S_i^2), and Spatial variance of Lin and Binns (LBV), in order of equations 1, 2, 3, 4 and 5.

$$\sigma_i^2 = \left[\frac{p}{(p-2)(q-1)}\right] w_i^2 - \frac{ss(GE)}{(p-1)\,(p-2)(q-1)} \quad (1)$$

$$w_i^2 = \sum j[\bar{y}_{ij} - \bar{y}_{io} - \bar{y}_{oj} + \bar{\bar{y}}]^2 \quad (2)$$

$$Y_{ijk} = M + p_i + (1+\beta_j)V_j + \delta_{ij} + \varepsilon_{ijk} \quad (3)$$

$$S_i^2 = \frac{\sum(x_{ij} - \bar{x}_i)^2}{q-1} \quad (4)$$

$$\text{Spatial Deviation C.V} = \frac{\text{Standard Deviation}}{\text{Means of treatment}} \times 100 \quad (5)$$

Results and Discussion

Result of composite variance analysis of two years and two location for grain yield shows in Table 2. Main effects of location and main effect of years and year ×location and year ×genotype × location interaction were significant at 1%, 5%, 5% and 1% level of probability, respectively. Mean comparison of yield in two location and two years shows that highest yield (7117 Kg/ha) exist in Mashhad Station Research in 2nd year of experiment. However mean of yield in two years have not significant in Mashhad Station. Least yield belong to Birjand station in first years with 5789 Kg/ha (Table 3). Yield mean of Mashhad was higher to Birjand in every of years. In general, Mashhad station has been considered to access the potential performance of new lines and Birjand station to evaluate triticale lines in difficult conditions (low rainfall and high temperatures in early spring) with marginal land and low yields.

No significant effect in genotype means that the genetic variation not exist among varieties of triticale in this experiment (Table 2). Significant main effect of location and year stats a significant difference in grain yield of two station of Mashhad and Birjand and within two years of the experiment (Table 2). On other hand, Two-way interaction between genotype × location and genotype × year were not

Table 2
Composite variance analysis of grain yield in first and second year of experiment

Source of variation	df	Mean of Squares	F
Location	1	7314994.504	115.475**
Replication(Location)	4	207969.921	-
Year	1	3010784.4	4.7528 *
Location*Year	1	1729413.37	2.7301 ns
Replication*Year(L)	4	1236704.246	-
Genotype	19	813048.364	1.2835 ns
Genotype*Location	19	530553.592	0.837 ns
Genotype*Year	19	1097406.829	1.7324 ns
Genotype*Location*Year	19	1867596.862	2.9482*
Error	152	633471.31	
C.V %	12.17		

* and ** significant at 5 % and 1% probability levels, respectively.
ns: non-significant

Table 3
Year×Location interaction on grain yield of triticale genotypes during two years

Location	Years of running tests	
	2nd year	1st year
Research station of Mashhad	7117 a	7063 a
Research station of Birjand	6183 b	5789 b

Means in each rows and column, followed by at least one letter in common are not significantly different at the 5% probability level using Duncan's Multiple Range Test.

significant that means the reaction of genotypes in different locations and different years was the same. The three-way interaction of genotype × location × year was significant at 5% level (Table 2). Being significant three-way interaction, use of mean grain yield with stability analysis is logistic and necessary.

Comparison of yield results of triticale genotypes using LSD test was bring in Table 4. The highest grain yield belong to control 1(ET-79-17) (with 7023 kg/ha) and after that line 3 (6904 kg/ ha). The grain yield of 10, 11, 16 and 19 lines are significantly lower than the control 1 (Table 4). On the other, lines 12 and 20 had significantly higher grain yield than the control 2 (Sanabad) (respectively 6753 and 6787 kg/ha). The average grain yield of control 2 was 6730 kg /ha. (Table 4).

Weather conditions, especially in Birjand station, had an impact on test results and the average grain yield of triticale genotypes. Now reported that cultivars of triticale in equal conditions, have the power to compete with maximum yielding wheat cultivars, even be superior in some cases such as drought and salinity conditions (Dosul and Fundo, 1990).

Stability parameters as environmental variance, coefficient of variation, regression coefficient, Shukla's variance, Wrick's equivalence and mean square of Lin and Binns for 20 genotypes tested in two years and location were calculated and the results are presented in Table 4.

The results of ranking analysis showed that lines 1, 12, 6 and 20 in addition to high performance, had a better ranking and lower standard deviation than others. Therefore these lines had greater yield stability (Table 4). Ranking of Line 3 was 7.5 and 7.77 for SDR. The average ranking of lines 12, 6 and 20 were 6, 6.5 and 6.5, respectively and, 4.24, 0.707 and 4.95, respectively for SDR (Table 4).

Sanabad and ET-79-17 line as high yielding genotypes who participated in this study as a control. ET-79-17 had the highest yield and the best ranking (1.5).

Based on the stability analysis of environmental coefficient of variation (CV) on 4 environment, the lowest CV among genotypes belong on lines No. 3, 19 and 18 (with the 2.7%, 4.5% and 7.7%, respectively). So based on this parameter, these genotypes are stable. CV parameter is based on the concept of biological sustainability, According to this concept, firstly, there is a correlation between yield and stability, i.e. stable genotypes usually have lower yield and, secondly, by increasing environment number, it was difficult to achieve a genotypes with high yielding and stability (Bakhshaieshi, 2012). In these method, lines no. 1 and 12 were identified as stable genotypes.

Lines no. 3, 6, 12 and 20 showed the least variance in Shukla's stability variance method. Also line 3 had a highest average yield.

In equivalence Wrick's method, lowest values belong to lines no. 1, 6, 12 and 20, respectively. However, highest yields belong to lines 1 and 20.

Based on regression coefficients of Finlay and Wilkinson, lines no. 1, 6, 12 and 20 had a indexes close to 1 and identified as stable genotypes (Table 4), also based on variance of Lin and Binns method, also lines no. 1, 6, 12 and 20 genotypes introduced as the stable genotypes (Table 4).

According to researchers that some of them refuse some methods of stability and some others accepted these methods, however there is no acceptable and conclusive methods for determine stable lines (Bakhshaieshi, 2012), So with these stability methods, it appear in addition to the control 1, suggest lines no. 6, 12 and 20 that have been introduced as stable genotypes by a greater number of sustainability methods. Among these, Line 20 due to higher yield, can be introduced as an alternative lines of control 1.

Vahabzadeh et al. (2006) used Ebrahat and Russell re-

Table 4
Means and stability analysis of grain yield in triticale genotypes in two station (Mashhad and Birjand) and two years

No.	b_i	w_i^2	σ_i^2	S_i^2	$\bar{R}_i$	(CV%)	SDR	yield (Kg/ha)**	LBV
C-1	1.05	478.61	391.7	38.1	1.5	10.4	0.7	7023	8.70
C-2	1.17	2734.05	94.6	76.4	7.5	19.4	9.19	6730	15.69
3	1.25	1273.7	297.7	50.5	7.5	2.7	7.77	6904	12.30
4	0.81	905.9	405.8	57.1	10.0	16.4	7.07	6567	11.90
5	1.32	1763.1	542.2	89.3	9.5	13.7	3.53	6562	14.64
6	1.01	531.9	241.7	47.3	6.5	12.3	0.70	6660	8.59
7	0.85	1562.1	527.3	65.1	15.0	16.4	4.24	6336	1.47
8	0.92	1001.2	291.1	57.1	10.5	7.7	7.77	6550	12.36
9	0.92	1452.5	310.1	53.0	10.5	8.2	6.36	6547	11.50
10	0.83	989.7	379.6	75.2	17.5	8.9	2.12	6112	1.37
11	0.83	763.3	286.5	49.0	19.0	15.5	1.41	6014	9.56
12	0.97	528.5	219.8	42.0	6.0	15.8	4.24	6753	8.72
13	0.92	924.2	417.07	71.1	7.5	16.1	4.95	6692	12.35
14	1.42	3011.7	476.9	85.7	10.5	13.9	3.53	6520	15.60
15	1.25	745.7	312.02	49.9	8.5	11.7	0.70	6617	12.73
16	1.25	852.1	331.3	56.0	17.0	12.6	0.00	6262	11.36
17	1.34	756.2	369.7	77.7	15.0	17.1	5.65	6334	14.78
18	1.20	597.2	312.6	63.6	9.0	8.4	7.07	6583	12.30
19	0.95	1324.2	341.7	73.2	15.0	4.5	7.07	6206	12.23
20	1.10	532.7	252.5	51.1	6.5	7.4	4.95	6787	8.98

**: LSD (5%) = 622.4

Table 5
Spearman correlation coefficients of stability parameters according to means of composite data of grain yield in triticale genotypes

	Yield	SDR	CV	Ri	S_i^2	σ_i^2	w_i^2	b_i	LBV
Yield	1								
SDR	0.17 ns	1							
CV	-0.10 ns	-0.1 ns	1						
Ri	-0.96**	-0.06 ns	0.07 ns	1					
S_i^2	-0.43 ns	0.32 ns	0.27 ns	0.43 ns	1				
σ_i^2	-0.14 ns	0.09 ns	0.49 ns	0.18 ns	0.72**	1			
w_i^2	-0.35 ns	0.39 ns	0.1 ns	0.42 ns	0.71**	0.60**	1		
b_i	0.25 ns	-0.07 ns	-0.01 ns	-0.24 ns	0.24 ns	0.14 ns	0.04 ns	1	
LBV	-0.12 ns	0.40 ns	0.21 ns	0.19 ns	0.72**	0.53*	0.62**	0.53*	1

* and ** significant at 5 % and 1% levels, respectively. ns: non-significant

gression analysis, Shukla's stability variance, Wrick's equivalence, environmental CV, coefficient of determination and non-parametric method (Ranking) to check the compatibility and sustainability yield of 19 promising lines of triticale in 3 research station of Mashhad, Zabol and Moghan during the years 2001 to 2002 and finally, introduced 5 lines as stable.

To investigate the correlation between estimated stability parameters in the present study, the correlation coefficients with each other and with yield parameters were evaluated and the results are presented in Table 5. Based on the results of Spearman correlation analysis, there is no significant correlation between all sustainability parameters with yield except average ranking (Ri) and correlation between this parameter with yield is negative and significant at 1% probability level (Table 5). There are significant positive correlation between CV stability parameter and Shukla's stability variance, spatial variance of Lin and Binns, Wrick's equivalence at 1% probability level.

Wrick's equivalence had a positive and significant correlation with Shukla's stability at 1% probability level (Table 5). This significant positive correlation has been previously reported in wheat, oat and barley (Bakhshaieshi Gheshlagh, 2012; Karimizadeh et al*.,* 2009; Eagles, and Frey, 1977). There are significant positive correlation between spatial variance of Lin and Binns parameters and Shukla's stability variance, Wrick's equivalence, regression coefficient of Finley and Wilkinson (Table 5).

Conclusions

According to the results of comparing the means and other sustainability parameters such as average ranking, Shukla's stability variance, Wrick's equivalence, Finlay and Wilkinson's stability variance and spatial variance of Lin and Binns, lines no. 3, 6, 12 and 20, which are had higher relative yield were also selected as stable lines. Also environmental variance, Shukla's stability variance, spatial variance of Lin and Binns, Wrick's equivalence, Finlay and Wilkinson variance had a high correlation in various years. Repeatability is an important factor for estimation of stability parameters on consecutive years and each parameters that is repeatable or have a higher correlation with other parameters can be suitable one for determine sustainable genotype. (Karimizadeh et al*.,* 2009).

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