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Estimation of stability parameters for seed yield and its components in triticale and wheat genotypes under optimum and stress environments

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Abstract
Thirty genotypes comprising of wheat (*T. aestivum* and *T. durum*) and hexaploid triticale was studied in Randomized Block Design with three replications, under normal, saline and stress during 2016-17 to assess the stability of these genotypes for yield and its contributing traits. Analysis of variance of stability revealed highly significant variance due to environment for all traits which indicated differential effect of different environments. The variance for genotypic effect was highly significant indicating thereby differential response of all the genotypes. The genotypes like T-4037, T-4045, T-4047, T-4049, T-4050 and six *aestivum* genotypes namely RAJ-3765, RAJ-4079, RAJ-4083, WH-1105, RAJ-3077 and RAJ – 3777 gave average response for seed yield to change in environmental conditions as indicated by their unit regression and non-significant deviations suggesting average stability and wider adaptibility of these genotypes.

Keywords: wheat, triticale, environments, stability, adaptibility

Introduction
Wheat is the second most important cereal just after rice. About 85% area of wheat production is under common bread wheat *(Triticum aestivum* L. em. Theil) followed by maccaroni wheat *(T. durum* L.) occupying 14% area. Wheat is grown under diverse agro-climatic conditions leading to wide fluctuation in productivity level from region to region. Triticale is much more tolerant than wheat to both biotic and abiotic stressors and thus more suitable for cultivation in marginal areas (Ugarte *et al.*, 2007; Villegas *et al.*, 2010) [14, 15]. The synthetic cereal triticale (Triticosecale Wittmack) combines many desirable qualities of both Triticum and Secale parents. It has great relevance for increased food production and better nutrition. However, the popularization of triticale has been hampered due to its instability for grain yield. An important measure to enhance the pace of progress in this crop of recent origin is the enlargement of its genetic base through crossing well adapted high yielding triticales. Triticale is quite different from other cereals in that it shows wider adaptability and high nutritional quality (Oettler, 2005) [11] as well as high yield potential, and it is generally more competitive against weeds than wheat is (Beres *et al.*, 2010) [1]. It also shows greater tolerance toward drought and pests than its progenitors (Darvey *et al.*, 2000; Erekul and Kohn, 2006) [2, 4]. Since the growing period of the crop becomes restricted due to sudden increase in the temperature after winter; the sowing time has an important bearing on production potential of a genotype. Temperature stress, drought and salinity is the major problems limiting wheat production. Therefore, as an alternative to more sensitive crops such as wheat and barley, triticale varieties are being developed with the aim of improving grain yields. Crop breeders have been improving to develop genotypes with superior grain yield, quality and other desirable traits over a wide range of different environmental conditions. The presence of genetic variation within a plant population is very important in achieving an effective breeding program (*i.e.*, in terms of yield and other agronomic traits). Moreover, in intensive production system, farmers have to adjust the sowing time to suit different crops. The stable performance of a variety plays an important role in high productivity. Hence, the main breeding objective is always aimed at to develop high yielding varieties showing good degree of stability over a wide range of environmental conditions.

Material and Methods

The material comprising of 11 triticale, 10 bread wheat and 9 durum wheat genotypes (Table-1) was planted in Randomized Block Design with three replications under three environments differentiated in to under normal (six irrigation) E_1, saline (six irrigation 4 Ec) E_2, stress (three irrigation) E_3 (Table-2) during *rabi* 2016-17. The observation were recorded on the randomly selected plants of each genotypes from each replication and environment for eleven character *viz*., days to 50% flowering, days to maturity, plant height, number of effective tillers per plant, number of grain per spike, spike length, 1000- seed weight, biological yield per plant, harvest index, protein content, seed yield per plant. Stability analysis was done as per Eberhart and Russel (1966) [3].

Table 1: List of parental materials used for present investigation

S. No.	Triticale genotypes	S. No.	Aestivum genotypes	S. No.	Durum genotypes
1.	T-4032	1.	RAJ-3765	1.	WHD-959
2.	T-4033	2.	RAJ-4037	2.	WHD-912
3.	T-4036	3.	RAJ-4079	3.	WHD-948
4.	T-4037	4.	RAJ-4083	4.	WHD-896
5.	T-4038	5.	WH-1105	5.	WHD-960
6.	T-4045	6.	RAJ-3077	6.	DBW-314
7.	T-4046	7.	RAJ-1482	7.	WHD-962
8.	T-4047	8.	RAJ-3777	8.	WHD-943
9.	T-4048	9.	RAJ-4238	9.	WHD-961
10.	T-4049	10.	RAJ-4120		
11.	T-4050				

Table 2: Details of environments used for present investigation

Normal Environment	Stress Environment	Saline Environment
No. of water = Six Recommended dose of N:P:K :Zn(120:40:20:5) Per hectare	No. of water = Three Half dose of N:P:K:Zn(120:40:20:5) Per hectare	No. of water = Six with 4 EC Recommended dose of N:P:K :Zn(120:40:20:5) Per hectare

Results and discussions

The analysis of variance for individual environment as well as pooled over environments showed that mean differences between genotypes were highly significant for grain yield and its components indicating thereby the presence of genetic variability among genotypes included in the present study.

The phenotypic stability of genotypes was measured by the parameters namely mean performance over environments (X), the linear regression (bi) and deviation from regression (S^2d_i). The stability parameters for all the eleven traits are presented in Table -3. A variety or strain is likely to be stable over different environments if it shows high mean values (above average performance), unit or less than unit regression coefficient (bi) with lowest non-significant deviation from regression (S^2d_i).

In the present study the estimation of regression coefficient and deviation from regression varied from genotype to genotype. Stability of eight genotypes for days to maturity can be predicted, which possessed non-significant deviation with mean lower than general mean and bi = 1. The five triticale genotypes namely T-4032, T-4033, T-4036, T -4047, T – 4048 and two *aestivum* wheat genotypes WH-1105 and RAJ-3777 were considered most stable and desirable for days to maturity, if varied environment is provided as they possessed lower mean value then general mean, b = 1 and least and non-significant S^2di.

For plant height nine well performing genotypes showed to be average stable whereas genotypes T- 4033 and DWB - 314 proved to be best under saline and stress environments as they showed lowest mean performance than population mean coupled with significant regression coefficient less than unity and least deviation from regression.

In case of spike length, triticale genotypes T - 4046 and T - 4045 could be utilized for normal and poor environments as they follow stability parameters. The six genotypes *viz.*, T - 4050, RAJ - 3765, RAJ - 4083, WH - 1105, RAJ - 4238 and RAJ - 4120 had significantly higher spike length than general mean, regression coefficient equivalent to unity and S^2d_i equivalent to zero, exhibiting average stability and adaptability, hence, most suitable and desirable.

Significant reduction in grains per spike was noticed in durum and aestivum as they shown to be most susceptible for drought and salinity stress. Triticale genotypes T-4036, T-4037, T- 4045, T- 4046, T- 4048, T- 4047, T- 4049, T- 4050 and aestivum genotypes RAJ - 3765 and WH-1105 had significantly higher mean values than general mean, regression coefficient equivalent to unity and S^2di non-significant and equivalent to zero indicating their suitability for normal, saline and stress environments. Madariya *et al*. (2001) also reported the similar findings.

It was well established that number of productive tillers contributes in increasing the yield under stress conditions. The results showed that genotypes viz., WHD - 960, RAJ - 3765, RAJ - 4037, RAJ - 4079, WH-1105, RAJ-3077, RAJ-1482 and RAJ-4238 had higher adaptability and stability and may be recommended for normal, saline and stress conditions. RAJ-4083 proved to be best under saline and stress environments with respect to number of effective tillers per plant as it possessed above average stability. Reduced number of effective tillers was shown by triticale genotypes under stress condition. These results are also similar with the earlier findings of Jaydeep *et al*. (2006) [5].

For 1000- seed weight, eight genotypes namely T-4046, T-4049, WHD-959, WHD-912, WHD-948, WHD-962, WHD-943 and WHD-961 were found to be stable across the environments for normal, saline and stress environments having significantly higher 1000-seed weight than general mean along with regression coefficient equivalent to unity as indicated by non-significant deviation from regression. Durum genotype DBW 314 possessed high mean value than population mean with b_i value less than unity and S^2d_i equivalent to zero, therefore well suited for poor environment ie. Saline and stress conditions. Najeeb *et al.* (2004) [10] also reported the similar results.

Out of 30 genotypes ten genotypes namely T-4045, T-4046, T-4047, T-4048, T-4049, T-4050, RAJ-3765, RAJ-4079, RAJ-4083 and WH 1105 were most stable and suitable for all types of environments due to their high mean performance with b_i value equal to unity and S^2d_i equivalent to zero for biological yield (Sharma *et al*. 2003) [13].

The genotypes T-4033, RAJ-4079 and RAJ-4083 were average in response to change in environmental condition as indicated regression coefficient near unity, higher mean and least S^2di suggesting average stability and wider adaptability of these genotypes for harvest index. Kumar R. (2012) [7] reported the similar results for harvest index.

Eleven genotypes *viz.* T-4032, T-4033, T-4036, T-4037, T-4038, T-4046, T-4047, T-4049, WHD-962, WHD-943 and

WHD-961 had higher mean performance value than population mean with b_i value equal to unity and S^2d_i equivalent to zero, found to have higher protein content over all the three environments. Triticale genotypes were found to have higher protein contents than durum and aestivum under different environmental conditions. Findings similar to these results were also reported by Saleem *et al*. (2015) [12].

Out of thirty genotypes tested higher seed yield was recorded in five triticale genotypes like T-4037, T-4045, T-4047, T-4049, T-4050 and six aestivum genotypes namely RAJ-3765, RAJ-4079, RAJ-4083, WH-1105, RAJ-3077 and RAJ - 3777 than the general mean with bi = 1 and s^2d_i least and non-significant, hence, these genotypes could be recommended for general cultivation in all types of environments i.e. normal, saline and stress. Similar finding were also reported by Mohammadi *et al.* (2012) [9] and Kava *et al*. (2016) [6].

Conclusions

Considering data obtained, none of the genotypes were found suitable for good and poor environments for seed yield. It is revealed that out of 30 genotypes none of the genotypes exhibited stability for all the character but the genotypes *viz.*, T- 4049, T- 4047, RAJ-3765 and WH 1105 have shown stable and predictable genotype x environment interactions for more than three characters over the environments. These specific genotypes reported stable performances not only for seed yield but also for the yield contributing traits. It was concluded that most of the triticale genotypes proved to have average stability for seed yield along with other yield attributing characters. Results proved that triticale genotypes were more competitive as compared to wheat genotypes for abiotic stresses such as drought, extreme temperature and salinity.

Table 3: Estimation of stability parameters for different observations included in the present studies

Genotypes	Days to 50% flowering			Days to maturity			Plant height		
	Mean	Bi	S²di	Mean	bi	S²di	Mean	bi	S²di
T-4032	72.77*	1.24	-0.10	111.66*	0.92	-0.09	69.27*	1.28	0.05
T-4033	71.66*	0.31	0.39 *	111.44*	0.91	0.07	68.84*	0.58**	-0.77
T-4036	70.77*	0.93	0.26	114.22*	0.94	0.23	68.29*	0.85	-0.16
T-4037	70.77*	1.00	-0.08	114.33*	0.90	0.36*	70.40	0.66	1.48
T-4038	81 .55	0.42	0.18	118.11	1.06	0.17	70.25*	-0.03	0.10
T-4045	79.33	0.47	1.04 **	112.44*	0.86	0.52*	79.66	1.85	0.04
T-4046	74.55	1.38	0.98**	116.33*	0.90	0.36*	84.37	1.81	2.23
T-4047	72.55*	0.50	1.69 **	111.88*	0.99	-0.06	84.15	1.56	4.83**
T-4048	71.55*	0.66	0.09	113.77*	1.10	-0.08	84.71	1.03	-0.18
T-4049	74.55	0.34	0.85 **	118.11	0.98	0.12	79.16	0.71	-0.65
T-4050	77.00	1.19	0.07	115.22*	1.17	11.19**	80.20	1.11	-0.37
WHD-959	71.66*	1.10*	-0.1 1	119.66	0.97	6.43**	64.77*	0.89	0.02
WHD-912	82.78	-0.19	0.27	117.22	0.91	-0.08	63.70*	-0.58	5.83**
WHD-948	75.44	0.68	0.40 *	122.11	1.06	0.17	63.97*	1.10	1.43
WHD-896	84.78	1.24	-0.10	120.22	0.90	0.81**	68.02*	0.29	-0.36
WHD-960	79.78	0.45	0.53 *	120.44	1.04	0.41*	63.68*	1.57	12.23**
DBW-314	77.56	0.98	-0.11	117.00	1.02	0.03	66.64*	0.05**	-0.77
WHD-962	78.78	1.24	-0.10	117.55	1.26**	-0.10	64.93*	1.71	7.95**
WHD-943	79.89	1.30	0.25	119.66	1.28	1.07**	65.03*	1.47	9.65**
WHD-961	81 .55	0.50	1.69**	121.11	1.23	4.83**	69.04*	0.78	0.34
RAJ-3765	70.22*	1.45	-0.05	117.11	1.11	3.52**	69.44*	1.21	7.01**
RAJ-4037	67.88*	1.06	0.15	119.88	1.11	3.65**	71 .04	0.29	0.71
RAJ-4079	67.77*	1.40	0.49 *	114.00*	0.86	1.02**	68.45*	0.57	12.54**
RAJ-4083	71.00*	1.03	0.50*	124.66	0.90	0.36*	68.33*	0.49	2.40
WH-1105	67.88*	1.53	0.36*	115.33*	1.04	0.90	76.12	1.60	0.44
RAJ-3077	74.00*	1.67	0.24	125.22	0.90	0.81**	72.89	1.89	9.87**
RAJ-1482	75.67	1.51	0.80 **	120.77	0.95	-0.10	72.63	1.57	4.22
RAJ-3777	74.00*	1.67	0.24	115.88*	0.99	-0.06	72.52	1.37	11.70**
RAJ-4238	69.11 *	1.16	0.36 *	119.55	0.90	0.81**	67.29*	1.25	-0.02
RAJ-4120	74.78	1.80	0.14	121.88	0.84	-0.10	72.04	1.10	0.05
GENERAL MEAN	74.72			117.56			71.33		
SE	0.18			0.29			0.50		
CD (P=0.05)	0.37			0.60			1.03		

Genotypes	Spike length (cm)			Number of grains per spike			Number of effective tillers per plant		
	MEAN	Bi	S²di	MEAN	bi	S²di	MEAN	bi	S²di
T-4032	5.98	0.74	0.68*	43.22	0.74	-2.28	4.69	1.17	-0.01
T-4033	6.10	0.54	-0.08	38.22	0.73*	-3.1 5	4.07	1.19	-0.02
T-4036	6.33	0.85	0.07	49.55*	0.99	-2.90	4.02	1.28	0.01
T-4037	6.25	-0.47*	-0.14	54.33*	0.97	-2.49	4.93	1.20	0.07
T-4038	6.90	-0.04	1.46**	43.00	1.09	28.02**	4.38	1.33	0.07
T-4045	7.95*	0.24*	-0.14	49.55*	1.06	-2.99	4.78	1.15	0.01
T-4046	8.46*	1.70*	-0.14	52.44*	0.59	-2.65	4.56	1.01	0.00

T-4047	9.61*	1.96	1.04**	55.00*	1.27	-0.07	4.36	0.91	005
T-4048	7.52*	1.16	2.98**	46.22*	0.44	0.28	4.28	0.78	001
T-4049	8.08*	-0.60	2.01**	53.77*	0.46	2.63	4.33	0.92	0.11
T-4050	7.39*	-2.05	0.13	45.77*	0.26	-2.75	4.09	1.17	-0.01
WHD-959	4.70	0.55	0.01	34.67	1.38	14.95*	3.87	0.93	-0.04
WHD-912	5.53	-0.09	0.07	33.22	0.92	-3.12	4.00	1.43	0.76**
WHD-948	5.64	-0.57	0.27	31 .22	1.27	-2.56	4.49	1.49	0.03
WHD-896	6.02	-0.51	0.11	40.1 1	1.45	9.62*	4.42	1.17**	-0.07
WHD-960	5.22	0.23	-0.01	45.00*	1.94	21.32**	5.20*	1.16	-0.05
DBW-314	5.20	0.07	-0.10	37.33	1.29	1.67	4.51	0.97	0.14
WHD-962	5.35	1.67	0.04	44.00	1.82*	-2.77	4.49	1.15	-0.04
WHD-943	5.26	0.97	-0.02	38.22	1.50	11.08*	4.84	1.08	-0.01
WHD-961	6.20	1.49	0.00	39.1 1	1.96	62.09**	4.36	1.11	-0.05
RAJ-3765	7.58*	3.71	-0.05	44.55*	1.05	-2.50	6.04*	0.93	0.15
RAJ-4037	7.19	1.89	-O.11	32.56	0.78	-2.41	6.02*	0.73	-0.02
RAJ-4079	7.08	2.85*	-0.14	41.56	0.78	-3.03	6.31*	0.65	-0.06
RAJ-4083	7.32*	2.41	-0.13	42.67	0.79	18.44**	5.84*	0.60*	-0.06
WH-1105	8.50*	2.77	-0.09	44.11*	0.50	-2.83	5.73*	0.89	-0.04
RAJ-3077	7.34*	1.48	0.81*	36.11	0.79	-3.14	5.90*	0.88	0.00
RAJ-1482	7.76*	2.26	0.66*	38.89	1.01	-1.81	5.70*	0.65	0.02
RAJ-3777	7.54*	2.42	2.13**	41.67	0.51	8.01	5.51*	0.73	0.31*
RAJ-4238	7.76*	0.41	-0.02	36.78	0.86	-2.96	5.94*	0.48	0.07
RAJ-4120	7.26 *	1.95	0.03	42.11	0.82	24.47**	4.73	0.84	0.08
General Mean	6.83			42.50			4.88		
SE	0.18			0.73			0.08		
CD (P=0.05)	0.38			1.51			0.17		

Genotypes	1000- Seed weight (g)			Biological yield per plants (g)			Harvest index (%)		
	MEAN	Bi	S^2di	MEAN	bi	S^2di	MEAN	bi	S^2di
T-4032	37.35	0.91	-0.04	31 .43	1.02	-0.77	34.07	1.07	0.96
T-4033	40.26	0.92	-0.02	29.63	0.68	1.83	37.00*	1.03	-1 .35
T-4036	36.58	1.16	-0.06	34.22	0.87	-0.89	34.42	0.73	-1.31
T-4037	33.94	0.95	0.68**	33.42	1.37	-2.15	37.95*	1.52	8.13**
T-4038	39.17	0.95	1.25**	33.89	0.76	4.03	30.49	0.23	14.95**
T-4045	40.67	1.01	-0.08	35.53*	1.04	4.14	39.24*	1.47	13.83**
T-4046	55.94*	0.91	0.02	36.89*	1.01	0.29	32.45	0.48	0.20
T-4047	39.31	1.00	-0.08	37.99*	1.07	0.95	33.36	1.00	-0.76
T-4048	36.95	1.22	0.43*	35.26*	1.31	2.57	34.24	1.63	-1.20
T-4049	45.49*	1.04	0.15	36.98*	1.64	3.99	38.85*	2.56	15.14**
T-4050	40.63	0.88	0.76**	40.28*	1.36	-3.00	34.59	1.68	2.96
WHD-959	55.71*	1.08	0.19	32.48	1.33	-3.28	32.94	1.62	0.30
WHD-912	43.22*	0.91	-0.03	31 .84	1.26	10.42*	34.39	1.81	2.49
WHD-948	49.56*	0.92	-0.07	31 .92	1.38	-3.41	33.87	2.67	1.40
WHD-896	50.68*	0.96	0.86**	30.74	1.10	-3.09	30.20	0.24	-1 .16
WHD-960	39.34	0.93	-0.02	30.88	1.15	-1 .84	30.88	0.45	-0.85
DBW-314	55.44*	0.90**	-0.09	32.17	1.10	3.56	33.43	0.44	5.56*
WHD-962	57.39*	0.99	004	30.87	1.21	-0.56	30.98	0.93	-0.58
WHD-943	59.75*	1.08	0.22	31 .14	1.52	-0.92	37.57	1.92	11.60**
WHD-961	55.88*	1.13	0.23	29.32	1.24	-0.49	31 .83	1.84	-O.76
RAJ-3765	35.84	1.08	0.02	40.15*	0.47	-3.27	34.34	-0.54	18.37**
RAJ-4037	37.91	1.02	-0.05	30.70	0.48	3.05	34.03	0.17	0.63
RAJ-4079	37.03	0.93	-0.07	39.79*	0.84	-0.69	40.68*	1.29	-1.23
RAJ-4083	38.13	1.32	12.76**	38.47*	0.81	0.24	38.00*	0.17	-0.26
WH-1105	37.40	0.89*	-0.09	36.22*	0.87	-3.44	35.48	1.75	-1.23
RAJ-3077	34.63	0.99	-0.05	34.18	0.63**	-3.56	37.10*	0.80	19.16**
RAJ-1482	36.55	1.13	0.28*	32.04	0.47	0.56	34.71	-0.55	32.48**
RAJ-3777	39.49	0.93	0.77**	41 .92*	1.28	11.71*	36.94*	1.98	4.38*
RAJ-4238	33.87	0.95	0.25*	30.57	0.22	-2.90	34.50	-0.26	6.91*
RAJ-4120	39.58	0.91*	-0.09	32.39	0.50	-2.19	36.26*	-0.16	18.15**
GENERAL MEAN	42.79			34.11			34.82		
SE	0.21			0.51			0.67		
CD (P=0.05)	0.43			1.04			1.38		

Genotypes	Protien content			Seed yield per plant		
	Mean	bi	S^2di	Mean	bi	S^2di
T-4032	14.06*	1.26	-0.05	10.53	0.84	0.00
T-4033	14.28*	1.07	-0.01	10.83	0.61	-0.46
T-4036	14.21*	1.17	0.06	11.71	0.93	-0.53
T-4037	14.28*	1.04	0.02	12.68*	0.97	-0.29
T-4038	14.24*	1.22	0.04	10.20	0.48	-0.37
T-4045	13.82	1.02	-0.05	13.61*	0.67	1.55
T-4046	14.04*	1.18	-0.02	11.96	1.20	-0.56
T-4047	14.07*	1.12	0.01	12.47*	0.87	-0.22
T-4048	13.98	1.03	-0.08	11.76	1.20	-0.70
T-4049	14.54*	1.20	-0.08	13.50*	1.40	-0.18
T-4050	14.01	1.05	-0.07	13.52*	1.04	.-0.60
WHD-959	13.73	0.81	0.17	10.35	1.11	-0.72
WHD-912	13.70	0.81*	-0.09	10.58	1.25	-0.73
WHD-948	13.36	1.27	0.23	10.18	1.02	-0.14
WHD-896	13.88	1.10	0.08	9.27	1.18	-0.40
WHD-960	13.82	1.08	0.01	9.47	1.15	-0.49
DBW-314	13.99	1.19	0.13	10.79	1.49	-0.26
WHD-962	14.36*	1.10	-0.08	9.37	1.04	0.25
WHD-943	14.59*	0.91	-0.05	11.12	1.43	-0.64
WHD-961	14.64*	0.92	-0.07	9.03	1.06	-0.07
RAJ-3765	13.24	0.99	-0.06	13.88*	1.14	-0.59
RAJ-4037	13.25	1.06	-0.08	10.41	0.57	0.13
RAJ-4079	13.39	0.61	1.07**	16.05*	0.85	0.82
RAJ-4083	13.31	0.67	0.46*	14.65*	1.21	-0.71
WH-1105	13.94	0.55	0.64**	12.64*	0.64	0.89
RAJ-3077	13.25	1.17	-0.06	12.67*	1.01	0.88
RAJ-1482	13.64	0.66	-0.04	11.27	1.24	-0.20
RAJ-3777	13.08	0.77	0.04	14.07*	0.79	-0.28
RAJ-4238	13.17	0.77	0.08	10.60	0.57	-0.67
RAJ-4120	13.22	1.20	0.10	11.65	1.06	0:12
GENERAL MEAN	13.83			11.82		
SE	0.10			0.19		
CD (P=0.05)	0.21			0.39		

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