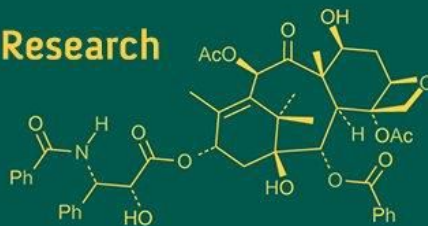


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Estimation of stability parameters for yield and its attributing characters in bread wheat [*Triticum aestivum* (L.) em Thell]

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Abstract

Understanding stability for grain yield in combination with the yield attributing traits would help in selecting stable genotypes in wheat, as this is presently required under the changing climatic condition. The present study was conducted with 45 wheat genotypes including two checks (HI 1544 and Raj 4079) under early sown, timely sown and late sown conditions (2022-2023) at the Instructional Agronomy Farm of Maharana Pratap University of Agriculture and Technology, Udaipur, India. The wheat genotypes differed significantly for all the seven morpho-reproductive traits. The G×E interaction was found to be significant for all the traits. In different traits different genotypes were found to be adaptable to favourable and unfavourable environments, created by the different dates of sowing. Overall, timely sown condition was found favorable for major yield component traits along with yield. Regarding stability for grain yield, the cross DBW 110 x WR 544 was identified as ideal and stable genotypes for grain yield per plant and can be recommended for cultivation in various seasons and different growing regions, whereas among all the parents Raj 4079 and GW-2014-596 demonstrated stability in favorable environments. These identified genotypes can be used to improve wheat cultivation and achieve reliable production.

Keywords: Wheat, grain yield stability, G×E Interaction, morpho-reproductive traits.

Introduction

Wheat (*Triticum aestivum* L.) is a major staple crop of South Asia and meets on an average 20 per cent calorie requirement of people in this part of the world (Joshi *et al.*, 2011) [13]. Wheat is consumed in different forms such as bread, macaroni (pasta), spaghetti, biscuits, doughnut, noodles, pizza, etc. However, in India, it is mostly consumed in the form of unleavened pan backed bread called chapatti. Apart from that, straw of wheat is used for feeding the cattle and now a days wheat is used for the production of ethanol and brewing of wheat beer. In India, the area under wheat has steadily gone up since the start of the wheat revolution in 1967 and its production and productivity have increased tremendously. With the introduction of new semi-dwarf and photo insensitive wheat genotypes during the 1960's, cultivation of wheat has been spread to new non-traditional areas like West Bengal, Assam and other eastern states of India. Production of wheat probably is increased by developing new cultivars having a broader genetic base with improved performance under different environmental conditions. But the changing climatic conditions and infestation of diseases and pests pose a great challenge to the breeders to select suitable genotypes with good adaptability to the local agro-climatic condition.

The superiority of genotypes depends on their stability across locations, years or environments. If the genotypes performance changes in different environments, then the interaction of the genotype x environment is an important factor to improve new cultivars. Genotype and its interaction with the prevailing environment is the basic factor determining the final yield. Therefore, analysis of any variance combined can measure GEI and identify main effectiveness; however, it is not enough to declare the GEI effectiveness. A variety or genotype is considered to be more adaptive or stable one, if it has a high mean yield but low degree of fluctuation in yielding ability, when grown over diverse environments. According to Eberhart and Russell (1966) [7] a stable variety should have around unit regression coefficient over environments ($b_i = 1$) and minimum deviation from the regression ($S^2_{di} = 0$)

in addition to higher seed yield than population mean (Patel *et al.* 2014) [23]. Thus, in order to have unbiased estimates of various genetic components, it is important that the experiment should be repeated over different environments. Grain yield and its components are complex functions of genotype, environment and genotype x environment interaction [$P = G + E + (G \times E)$] (Falconer 1989; Sharma 2001; Hamam *et al.*, 2009) [8, 27, 11]. Hence, it is always desirable to study the stability of genotypes in respect of economically important traits as it supports the need for specific breeding programmes in different environments (Stagnari *et al.*, 2013) [32]. In the present study, 45 wheat genotypes (13 parents, 30 crosses and 2 standard checks) have been studied for different yield attributing traits under three entirely different environments (*viz.*, early sown, timely sown and late sown condition) and stability parameters were analyzed.

2. Materials and Methods

The experiment was carried out with three dates of sowings *viz.*, early sown (E₁), timely sown (E₂) and late sown (E₃) at Instructional Agronomy Farm of Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan. The experimental material comprised of forty-five wheat genotypes (*Triticum aestivum* L.). Thirteen wheat genotypes (10 Lines and 3 Testers) were crossed in Line x Tester fashion during Rabi, 2021-22 to develop a total of thirty crosses. Two check varieties *i.e.* HI 1544 and Raj 4037 were also among the studied genotypes. These thirteen parents along with thirty hybrids and two checks were evaluated in Randomized Block Design with three replications during Rabi, 2022-23. Each genotype was accommodated in a single row plot of 2-meter row length maintaining crop geometry of 25 cm x 10 cm row to row

spacing and plant to plant spacing, respectively. All the recommended cultural practices will be adopted to raise a good and healthy crop. Seven quantitative characters were studied *viz.*, days to 50 per cent flowering, days to 75 per cent maturity, plant height (cm), number of effective tillers per plant, number of grains per spike, 1000-grain weight (g) and grain yield per plant (g). The data was collected from ten random plants selected from each plot in all three replications and an average value obtained was considered for further statistical calculations.

Stability Parameters: The statistical analysis of genotype x environment interaction and stability parameters were worked out by Eberhart and Russell (1966) [7] method for different traits. under study.

3. Results and Discussion

The pooled ANOVA (Table 1) revealed that the 45 wheat genotypes and the effects of environments differed significantly for all the seven morpho-reproductive traits over the three environments, created by the three different dates of sowing (early, timely and late sown). Similar findings have been reported earlier for all the traits under study by Krupal *et al.* (2018) [18]. Genotype x Environment (G x E) interaction was found to differ significantly for all the seven characters studied *viz.*, days to 50 per cent flowering, days to 75 per cent maturity, plant height, number of effective tillers per plant, number of grains per spike, 1000-grain weight and grain yield per plant indicating that stability analysis could be carried out among these genotypes for the concerned traits. Similar finding for genotype x environment interaction for all the traits studied was reported by Singh *et al.* (2017) [28].

Table 1: Pooled ANOVA for the seven morphological traits over the three environments

SN	Source	df	Mean sum of squares						
			Days to 50 percent flowering	Days to 75 per cent maturity	Plant height (cm)	Number of effective tillers per plant	Number of grains per spike	1000-grain weight (g)	Grain yield per plant (g)
1.	Environment	2	98.72**	12421.36**	204.03**	3.84**	22.08**	29.51**	110.92**
2.	Genotype	44	90.86**++	18.04**++	955.55**++	12.71**++	110.65**++	246.41**++	36.89**++
3.	G x E	88	8.28**	8.70**	45.77**	3.59**	14.60**	12.57**	6.14**
4.	Pooled Error	264	1.99	2.87	23.97	0.66	3.81	5.88	1.84

*, ** Significant against pool error and +, ++ against respective Env. interaction at 5% and 1% respectively.

Mean performance of wheat genotypes over three environments: The mean performance of the wheat genotypes over all the environments are given in the Table 2. The earliest flowering (71.54 days) and earliest maturity (113.86 days) was observed in late sown conditions (E₃). The late flowering was shown in environment 2 (73.24 days) and the longest maturity was shown in environment 1 (132.73 days). Out of the three environments, environment 3 gave highest mean for plant height (98.17 cm) and

environment 2 gave the lowest mean for plant height (95.72 cm) for the genotypes. Among the parents, minimum plant height was observed by Raj 4079 (90.26 cm) and among the crosses, minimum plant height was observed for DBW 173 x Raj 4079 (79.72 cm). For number of effective tillers per plant, out of all environments, environment 2 (timely sown) exhibited the highest mean (8.74) and environment 3 (late sown) exhibited the least mean.

Table 2: Performance of wheat genotypes over three environments

Environments	Days to 50 per cent flowering			Days to 75 per cent maturity			Plant height (cm)			Number of effective tillers per plant		
	E ₁	E ₂	E ₃	E ₁	E ₂	E ₃	E ₁	E ₂	E ₃	E ₁	E ₂	E ₃
Mean	72.58	73.24	71.54	132.73	126.30	113.86	97.10	95.72	98.17	8.56	8.74	8.40
CD 5%	2.01	2.55	2.26	2.84	2.67	2.74	8.29	7.95	7.58	1.30	1.31	1.35
CV (%)	1.71	2.15	1.95	1.32	1.30	1.48	5.26	5.12	4.76	9.36	9.26	9.87
S.Em (±)	0.72	0.91	0.81	1.01	0.95	0.97	2.95	2.83	2.70	0.46	0.47	0.48

E₁: Early sown, E₂: Timely sown and E₃: Late sown

For number of grains per spike, environment 1 (40.69) was observed to have shown the highest grains per spike (GPS) and environment 3 (39.95) gave the least mean GPS. For 1000 grain weight, environment 1 (53.56 g) was observed to show the highest value while environment 3 (52.63 g) was observed to show the least mean 1000-grain weight, respectively. Parent IC 427824 showed maximum estimates for 1000-grain weight (62.29 g) whereas, cross HTW 9 x Raj 4079 (65.01 g) showed maximum estimates for 1000-grain weight. For grain yield per plant, environment 2 was observed to exhibit the highest mean grain yield (19.13 g) and environment 1 had recorded least mean yield (18.25 g)

among all the three environments (Table 2). Evaluation of mean performance among the parents revealed that maximum grain yield per plant was exhibited by IC 427824 (19.87 g). Among the crosses, the maximum grain yield per plant was exhibited by cross WH 730 x DBW 187 (23.78 g). Related observations on the different grain yield attributes were also expressed by Kota *et al.* (2013) [17], Ahmad *et al.* (2014) [11], Kalhoro *et al.* (2015) [15], Kandil *et al.* (2016) [15], Gao *et al.* (2017) [9], Hassani *et al.* (2017) [12], Sood *et al.* (2017) [31], Rajput and Kandalkar (2018) [26] and Singh *et al.* (2020) [29].

Table 2: Contd.....

Environments	Number of grains per spike			1000-grain weight (g)			Grain yield per plant (g)		
	E ₁	E ₂	E ₃	E ₁	E ₂	E ₃	E ₁	E ₂	E ₃
Mean	40.69	40.04	39.95	53.56	53.14	52.63	18.25	19.13	17.31
CD 5%	3.19	3.10	3.20	3.52	4.08	4.17	2.10	2.27	2.24
CV (%)	4.83	4.78	4.94	4.05	4.74	4.88	7.08	7.32	7.96
S.Em (±)	1.14	1.10	1.14	1.25	1.45	1.48	0.75	0.81	0.80

E₁: Early sown, E₂: Timely sown and E₃: Late sown

Stability analysis: The ANOVA for stability analysis as per Eberhart and Russell (1966) [7], indicated highly significant differences among the wheat genotypes for all the traits studied over three different environments, indicating that sufficient variability was present among the genotypes for the traits studied (Table 3). Similar views were opined by Krupal *et al.* (2018) [18] and Hamam *et al.* (2009) [11]. The components after partitioning of the mean sum of squares like the genotypes and environment + (genotype x environment) were found to be significant for all the characters, which indicated presence of genetic variability in the wheat genotypes under present study. The mean sum of

squares due to the environment along with linear component of environment were significant for all the characters, suggesting presence of variation among the three environments (early, timely and late sown) tested. The wheat genotypes differed significantly for all the characters, which indicated differential response of the genotypes to the environments and independence of the genetic systems in determining the stability parameters. The genotype x environment (linear) component differed significantly for all the traits, which meant that the performance of the genotypes could be predicted across the environments for all the traits.

Table 3: Analysis of variance for stability of different characters in wheat

S. No.	Characters	Genotype	E+(G x E)	E (L)	G x E (L)	Pool dev.	Pool Err
		[44]	[90]	[1]	[44]	[45]	[264]
1	Days to 50 percent flowering	30.29**	3.43**	65.81**	2.04**	3.40**	0.66
2	Days to 75 per cent maturity	6.01**	94.85**	8280.90**	2.71**	3.02**	0.96
3	Plant height (cm)	318.52**	16.43**	136.02**	17.44**	12.79*	7.99
4	Number of effective tillers per plant	4.24**	1.20**	2.56**	1.26**	1.11**	0.22
5	Number of grains per spike	36.88**	4.92**	14.72**	4.68**	4.94**	1.27
6	1000-grain weight(g)	82.14**	4.31**	19.67**	3.03*	5.23**	1.96
7	Grain yield per plant (g)	12.30**	2.82**	73.95**	2.10**	1.95**	0.61

*, ** Significance at 5% and 1% level of probability, respectively against pooled error, respectively; +, ++ indicates the significance at 5% and 1% level of probability against pooled deviation, respectively. E- Environment, G-Genotype and L- Linear

The evaluation of mean and stability parameter (Table 4 and Table 5) for the seven morpho-reproductive traits revealed that for days to 75 per cent maturity, genotypes Raj 4079 (among the parents) and WH 730 x WR 544, DBW 150 x WR 544, IC 427824 x WR 544, WH 730 x Raj 4079 and DBW 150 x Raj 4079 (among the crosses) showed non-significant deviation from regression (S^2_{di}) and regression coefficient close to unity ($b_i=1$) with a mean value lower than the population mean (124.30 days), indicating their stability across the environment and suitable for early maturity (Table 4). For grain yield per plant, a single genotype DBW 110 x WR 544 was found (Table 5) to be stable and adapted to all the three environments, because of its mean performance greater than population mean with regression coefficient around unity ($b_i=1$) and non-significant deviation from regression (S^2_{di}). Parents Raj 4079 and GW-2014-596; eleven crosses *viz.*, WH 730 x

DBW 187, DBW 150 x DBW 187, WCF8BL10 x DBW 187, GW-2014-596 x DBW 187, GW 2014-596 x WR 544, DBW 110 x Raj 4079, HTW 9 x Raj 4079, DBW 150 x Raj 4079, WCF-12-208 x Raj 4079, WCF-1261 x Raj 4079 and GW-2014-596 x Raj 4079 had regression coefficient greater than unity ($b_i>1$) with mean value higher than population mean (18.23 g), indicating their stability under favourable environments. Similar trends for adaptability of genotypes were also observed by Al-Otayk (2010) [2], Altay (2012) [3], Kota *et al.* (2013) [17], Gogas and Sotiriou (2014) [10], Meena *et al.* (2014) [21], Mohammadi *et al.* (2014) [22], Temesgen *et al.* (2015) [33], Polat *et al.* (2016) [24], Bassi and Garcia (2017) [4], Solomon *et al.* (2018) [30], Thakur *et al.* (2019) [34], Dhiwar *et al.* (2020) [6], Kabir *et al.* (2020) [14], Malav *et al.* (2020) [20], Kshatri *et al.* (2021) [19], Chauhan *et al.* (2023) [5] and Prabhnath *et al.* (2024) [25].

Table 4: Stability parameters for Days to 75 per cent maturity and Grain yield per plant in wheat [Eberhart and Russel (1966)]

SN	Genotype	Days to 75 per cent maturity			Grain yield per plant		
		μ_i	b_i	S^2d_i	μ_i	b_i	S^2d_i
1	DBW 187	124.33	0.84	1.91	14.31	2.27	7.76**
2	WR 544	120.44	0.94	0.57	15.47	0.08	0.67
3	Raj 4079	123.78	1.02	-0.59	18.61	1.39	-0.56
4	DBW 110	122.44	0.72	1.37	16.62	-1.05	-0.60
5	HTW 9	123.67	0.90	-0.93	17.10	-0.58	3.26*
6	WH 730	123.44	0.76	1.88	16.27	-0.16	0.58
7	DBW 150	125.44	0.96	3.56*	14.00	2.10	2.65*
8	WCF-12-208	124.78	1.00	-0.93	14.73	0.42	1.11
9	WCF-1261	123.56	0.78	1.32	17.90	2.19	-0.53
10	WCF8BL10	126.00	0.94	-0.66	16.84	2.27	0.07
11	DBW 173	125.33	1.10	-0.49	17.02	-0.52	1.18
12	GW-2014-596	126.56	1.04	0.65	18.57	1.15	-0.39
13	IC 427824	124.67	0.95	0.86	17.06	2.43	1.68
14	DBW 110 x DBW 187	125.44	0.87	4.39*	18.90	-0.29	2.51*
15	HTW 9 x DBW 187	125.22	1.01	0.34	18.64	2.25	9.17**
16	WH 730 x DBW 187	123.44	1.05	9.18**	22.82	1.70	1.15
17	DBW 150 x DBW 187	123.11	1.14	9.54**	20.83	1.77	0.31
18	WCF-12-208 x DBW 187	123.11	0.80	-0.16	20.63	-0.57	-0.43
19	WCF-1261 x DBW 187	125.00	0.88	-0.68	18.88	-0.43	-0.56
20	WCF8BL10 x DBW 187	125.78	1.08	2.00	20.04	1.58	-0.51
21	DBW 173 x DBW 187	125.11	0.86	-0.56	17.90	1.85	2.10*
22	GW-2014-596 x DBW 187	126.00	1.01	-0.82	20.21	1.75	-0.30
23	IC 427824 x DBW 187	125.00	0.98	3.18*	18.34	0.14	1.83*
24	DBW 110 x WR 544	125.78	1.10	0.67	19.39	0.99	-0.61
25	HTW 9 x WR 544	126.89	1.08	-0.95	18.13	2.04	-0.31
26	WH 730 x WR 544	122.89	0.96	2.59	17.89	0.14	0.95
27	DBW 150 x WR 544	123.11	1.03	1.13	19.28	-1.38	4.68**
28	WCF-12-208 x WR 544	127.11	1.02	-0.59	19.17	-0.81	2.85*
29	WCF-1261 x WR 544	124.67	0.99	0.56	19.37	0.02	-0.35
30	WCF8BL10 x WR 544	122.00	1.05	3.90*	20.17	0.93	-0.59
31	DBW 173 x WR 544	124.22	0.94	21.23**	18.23	1.78	-0.10
32	GW-2014-596 x WR 544	125.33	0.99	-0.96	18.55	1.95	0.96
33	IC 427824 x WR 544	124.22	1.05	-0.78	20.20	1.99	2.56*
34	DBW 110 x Raj 4079	125.33	1.22	-0.94	20.73	1.33	-0.57
35	HTW 9 x Raj 4079	124.11	1.23	-0.09	18.28	1.60	-0.14
36	WH 730 x Raj 4079	123.67	1.05	-0.04	18.60	0.68	-0.61
37	DBW 150 x Raj 4079	122.56	1.00	-0.47	19.85	1.32	1.57
38	WCF-12-208 x Raj 4079	125.89	1.08	-0.95	18.60	2.38	-0.18
39	WCF-1261 x Raj 4079	123.67	1.08	14.61**	19.00	1.98	0.55
40	WCF8BL10 x Raj 4079	124.00	1.03	2.97*	17.37	-0.33	5.88**
41	DBW 173 x Raj 4079	123.67	0.83	13.04**	21.85	0.75	-0.06
42	GW-2014-596 x Raj 4079	122.78	1.08	2.00	18.34	2.63	0.32
43	IC 427824 x Raj 4079	125.00	1.13	1.51	17.73	2.42	0.10
44	HI 1544	122.33	1.19	-0.39	14.23	0.93	0.74
45	Raj 4037	122.44	1.23	-0.09	13.75	-0.09	10.17**

*, ** and +, ++ Significantly deviating from 0 and 1 at 5% and 1% respectively

Table 5: List of parents and crosses of wheat suitable for favourable, unfavourable and average environmental conditions for grain yield per plant

S. No.	Characters	Parents			Crosses		
		>(Favourable)	~(Variable)	<(Unfavourable)	>(Favourable)	~(Variable)	<(Unfavourable)
1.	Grain yield per plant (g)	Raj 4079, GW-2014-596	-	-	WH 730 x DBW 187, DBW 150 x DBW 187, WCF8BL10 x DBW 187, GW-2014-596 x DBW 187, GW-2014-596 x WR 544, DBW 110 x Raj 4079, HTW 9 x Raj 4079, DBW 150 x Raj 4079, WCF-12-208 x Raj 4079, WCF-1261 x Raj 4079, GW-2014-596 x Raj 4079	DBW 110 x WR 544	WCF-12-208 x DBW 187, WCF-1261 x DBW 187, WCF8BL10 x WR 544, WH 730 x Raj 4079, DBW 173 x Raj 4079

Conclusion

Mean performance of all the genotypes indicated that early sown (E_1) was best for number of grains per spike and 1000-grain weight, timely sown (E_2) was the best for the

characters viz., plant height, number of effective tillers per plant and grain yield per plant whereas late sown (E_3) was best for early flowering and early maturity. Overall, timely sown condition was found favorable for major yield

component traits along with yield. When the genotypes were grouped according to stability parameters as per Eberhart and Russel (1966), it was found that one genotype DBW 110 x WR 544 found to have stable performance under all the three viz., early, timely and late sown conditions in terms of yield. When stability for grain yield was taken into consideration, it was found that the wheat genotypes Raj 4079, GW-2014-596, WH 730 x DBW 187, DBW 150 x DBW 187, WCF8BL10 x DBW 187, GW-2014-596 x DBW 187, GW 2014-596 x WR 544, DBW 110 x Raj 4079, HTW 9 x Raj 4079, DBW 150 x Raj 4079, WCF-12-208 x Raj 4079, WCF-1261 x Raj 4079 and GW-2014-596 x Raj 4079 were found to be stable for rich environments i.e., timely sown condition thus they could be recommended for timely sown condition only. Genotypes like WCF-12-208 x DBW 187, WCF-1261 x DBW 187, WCF-1261 x WR 544, WCF8BL10 x WR 544, WH 730 x Raj 4079 and DBW 173 x Raj 4079 were found stable for unfavorable conditions thus they could be recommended for late sown and abiotic stressed conditions.

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