Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2582-2845.8274

ISSN: 2582 – 2845

Ind. J. Pure App. Biosci. (2020) *8*(4), 282-293

Indian Journal of Pure & Applied Biosciences

Peer-Reviewed, Refereed, Open Access Journal

Research Article

Grain Yield and Its Related Traits Stability Performance under Different Irrigated and Sowing Situations in Wheat (*Triticum astivum* L.)

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Received: 23.06.2020 | Revised: 11.08.2020 | Accepted: 19.08.2020

ABSTRACT

Twenty genotypes of common bread wheat (Triticum aestivum L.) were evaluated in 4 different environments viz., timely sown irrigated condition (E1), timely sown partially irrigated condition (E2), late sown irrigated condition (E3), and late sown partially irrigated condition (E4) to assess the stability of these genotypes for yield and its contributing traits over four environments in a randomized complete block design with two replications. Analysis of variance of stability with respect to different traits revealed that variance due to environment was highly significant for all characters except flag leaf width, which indicated the differential effect of different seasons. The variance for the genotypic effect was highly significant for all traits indicating thereby differential response of all the genotypes. The variance due to G x E interaction (linear) was highly significant for days to heading, tillers per plant, grain weight per spike, indicating a substantial amount of predictable G×E interaction. Timely sown partially irrigated condition (E2), irrigated late sown condition (E3) was found favorable for yield and its related attributes except for tillers per plant and canopy temperature. Genotypes, RVW-4272, and RVW-4278 were found stable and responsive in favorable conditions only. Based on stability parameters, genotype RVW-4271, RVW-4273, RVW-4274, RVW-4261, and RVW-4280 appeared as promising genotype and stability for grain yield for these genotypes was found associated with most of the yield attributes.

Keywords: *Yield, Stability analysis, Environment, G×E interaction, Regression coefficient*

INTRODUCTION

Wheat (*Triticum aestivum* L. emend. Fiori & Paol) is the main crop in the world most of the area. Being the second most important cereal crop, it also plays a significant role in the food and nutritional security of India. It is cultivated in a huge amount all over the country and thus providing a 30% contribution in the food basket of the country.

Cite this article: Dolhey, R., Kandalkar, V.S., & Kushwah, A. (2020). Grain Yield and Its Related Traits Stability Performance under Different Irrigated and Sowing Situations in Wheat (*Triticum astivum* L.), *Ind. J. Pure App. Biosci. 8*(4), 282-293. doi: http://dx.doi.org/10.18782/2582-2845.8274

India is the second-largest producer of wheat in the world with the production of around 75 million tonnes during last decade, it is a major contributor to the food security system in India, occupying nearly 30.23 million hectares, producing 93.50 million tonnes and productivity 30.93 q/ha. In Madhya Pradesh, it is cultivated in 5.911 million hectares, with the production of 17.689 million tones and productivity of 29.93 q/ha. (Anonymous, 2015-2016).

The substantial improvement in production is of utmost necessity not only to meet the ever-increasing food requirement for domestic consumption but also for export to earn foreign exchange. To feed the growing population, the country's wheat requirement by 2030 has been estimated at 100 million metric tonnes and to achieve this target. Wheat production has to be increased at the rate of <1% per annum (Sharma et al., 2011) and this can be achieved through horizontal approach, i.e., by the increasing area under cultivation or through vertical approach i. e. varietal/hybrid improvement, which is one of the strongest tools to take a quantum jump in production and productivity under various agro-climatic conditions.

The growing period of wheat is limited due to the eventual increase in temperature after winter. Therefore it is seen that under the diverse agroclimatic condition, there is wide fluctuation in wheat productivity varying from region to region (Banerjee et al., 2006). Thus varying environment has a huge impact on genotypic yield indicators. Due to genotype × environment interactions, varieties show inconsistent performance, as grain yield is a complex trait that largely depends on several contributing attributes. Therefore predictions about phenotypic stability can be of great use for effective selection of varieties as well as for future wheat breeding programs.

Allard and Bradshaw (1964) defined stability as an adaptation of varieties to unpredictable and transient environmental conditions. This method is used to select genotype, which is not much affected by environmental change. As we know, the productivity of a genotype depends on genotypic adaptation and stability depends on genotype-environment interaction. Therefore it is important to have an understanding of genotype-environment interaction at all plant breeding stages such as plant architecture, parental selection, selection based on traits, and selection based on yield (Jackson et al., 1996, Van and Hunt 1998).

The concept of stability has been defined in different ways, and several biometrical methods, including univariate and multivariate ones, have been developed to assess stability (Lin et al., 1986, Becker and Leon 1988, Crossa, 1990). The most widely used one is the regression method, based on regressing the mean value of each genotype on the environmental index or marginal means of environments (Romagosa & Fox 1993, Tesemma et al., 1998). A good method to measure stability was previously proposed by Finlay and Wilkinson (1963) and was later improved by Eberhart and Russell (1966). To predict the yield stability of a particular genotype under different situations, we should have an understanding of the nature of genotype-environment interaction. Thus prediction helps us to establish breeding objectives and recommending particular cultivar of optimum production in different areas (Singh & Chaudhary 2007). Therefore, an attempt was made to study the stability parameters of yield and its contributing traits of different bread wheat genotypes evaluated over four seasons.

MATERIALS AND METHODS

The experimental material consisted of 20 genotypes of wheat and its random allocation in different replication under different environments. Genotype RVW 4261 (25^{TH} SAWN 317/UP 2425), RVW 4262(CBW-38X-HW-5205), RVW 4263(15^{TH} SAWYT380/RAJ 4037), RVW 4264 (DBP 01-01/PDW 233), RVW 4265(HUW 206 / DBW 17), RVW 4266(CBW38/HW5205) ,RVW 4267 (35^{TH} IBWSN 435)/NW 1014), RVW 4268(35^{TH} IBWSN 159/BCW//CROC-1/AE.SW. (622)),RVW 4269(DDS 10-1272), RVW 4270(CBW-38X-HW-5205), RVW 4271(SONALIKA-

SENTHITEK-13), RVW 4272(DDS-10-1299) ,RVW 4273(DDS-10-1264) ,RVW 4274 (DDS-10-1299) ,RVW 4275(DDS-10-1299), RVW 4276 (DDS-10-1301) ,RVW 4277(SONALIKA-X-FL-2947), RVW 4278(DD-11-1363), RVW 4279(DD-11-1369), RVW 4280(DD-11-1370) were sown in different conditions. The experiment was conducted at the Research field of AICRP on wheat, College of Agriculture, Gwalior located in the Gird region (Agro-climatic zone No 6, wheat-pearl millet crop zone). The Gwalior is situated at an altitude of 211.52 MSL, 260 13´ N Latitude, and 780 14´ E Longitude. The soil is sandy loam, low in available nitrogen, medium in phosphorus and high in potash with a pH of 8.5. The summer is hot and dry; May and June are the hottest months. The maximum and minimum temperature varies between 47^0C to 28.5^0C, respectively. December and January constitute the cooler months of the year, and minimum temperature ranges from 4^0C to 10.8^0C. The average rainfall ranges between 80 to 90 cm, most of which are received in July, August, and September with few showers in winter months. During the wheat season, the maximum temperature was ranging from 19.8^0C to 43.5^0C and minimum temperature from 6.0^0C to 26.6^0C. The total rainfall received was 14 mm from October 2016 to April 2017. The overall season was favorable for crop growth

The experiment was conducted in a randomized complete block design with two replications in a 2-row plot of 2.5 m length at research farms, college of agriculture, Gwalior, MP. The sowing was done by dibbling seeds in rows with spacing of 20 cm apart and 4-6 cm within a row on November 15^{th} (Timely sown environment 2016-17) and December 3^{rd} (Late sown environment 2016-17). The trials were conducted under timely sown irrigated condition, timely sown partially irrigated condition, late sown irrigated condition, and late sown partially irrigated condition representing four different environments E1, E2, E3, and E4, respectively. The recommended packages of practices were adopted for optimum crop growth. The observations were recorded on the following 15 characters-Days to Heading, Days to maturity, plant height (cm), Tillers per plant, Spike length (cm), Peduncle length (cm), Flag leaf length (cm), Flag leaf width (cm), Spike weight per plant (g), Grain weight per spike (g), 1000 grain weight or Test weight (g), Grain yield per plant (g), Canopy temperature, Biological yield (g), Harvest index (%). Data were analyzed using the following methods.

Analysis for stability parameters: Eberhart and Russell (1966) model was used for the estimation of stability parameters-

$$b_i = \Sigma_j Y_{ij}\, l_j / \Sigma_j I_j^2 \quad (1)$$

Where

$\Sigma_i Y_{ij}\, l_j$ = sum of the i^{th} genotype × environmental index in the j^{th} environment and ΣI_j^2= environmental index

Regression coefficient (b_i): The first stability parameter regression coefficient of the varietal mean on the environmental index is estimated as-

$$b_i = \Sigma_j Y_{ij}\, l_j / \Sigma_j I_j^2 \quad (2)$$

Where

$\Sigma_i Y_{ij}\, l_j$ = sum of the i^{th} genotype × environmental index in j^{th} environment

ΣI_j^2= environmental index

Deviation from regression: The deviations are squared to provide an estimate of another stability parameter ($\bar{S}^2 d_i$)-

$$\bar{S}^2 d_i = [\frac{\Sigma \delta_{ij}^2}{e-2} - se^2/r \quad (3)$$

Where, se^2/r = Estimate of the pooled error, $\Sigma\delta_{ij}^2 = [\Sigma Y_{ij}^2 = y_{i.}^2/e\, \frac{(\Sigma_j Y_{ij})^2}{I_j^2}]$

RESULT

Analysis of variance

The analysis revealed a significant difference among the genotypes for all the studied characters including grain yield and its component traits in each environment and pooled over the environment, indicating the presence of a considerable amount of genetic variability among genotypes. The pooled analysis further revealed significant genotype x environment interaction for all the characters except peduncle length and plant height, indicating the presence of differential response of varieties for all characters in the different environments except plant height and peduncle length. The present findings are in agreement with the result of Singh et al. (2016), Bhardwaj et al. (2016), Gitonga et al. (2016), Meena et al. (2014), Singh et al. (2013), Kota et al. (2013) Ameen (2012), Banerjee et al. (2006), Yadav et al. (2009) and Gowda et al. (2010).

The analysis of variance of stability was carried out and presented in Table 1. It revealed that the variance due to the environment was highly significant for all characters except flag leaf width. The genotypic variance was significant for all traits. The variances due to G X E interaction (linear) had shown highly significant for days to heading, tillers per plant, grain weight per spike. Mean sum of square due to E + (V X E) interaction was highly significant for days to heading, days to maturity, tillers per plant, spike weight per plant, grain weight per spike, canopy temperature. Nine characters viz., tillers per plant, flag leaf length, spike weight per plant, grain weight per spike, thousand-grain weight, yield per plant, canopy temperature, biological yield, harvest index were having highly significant pooled deviation suggesting large fluctuations in the expression of all the characters over environments.

The defined knowledge on the nature and magnitude of genotype × environmental interaction is highly important in understanding the stability in yield of a particular variety for its better exploitation under given situations. This understanding can be used to establish breeding objectives, identify ideal test conditions, and formulate recommendations for areas of optimal cultivar adaptation (Singh & Chaudhary 2007). Stability analysis showed that variance due to the environment (linear) was significant for all characters except flag leaf width indicating the distinct and differential effect of different environments. The variance due genotype effect was highly significant for all characters indicating the differential response of all the genotypes. The variances due to G X E interaction (linear) was highly significant for days to heading, tillers per plant, grain weight per spike, indicating a substantial amount of predictable G X E interaction. Hence, it would be possible to predict the performance of genotype over a wide range of environments for these traits. Mean sum of square due to E + (V X E) interaction was highly significant for days to heading, days to maturity, plant height, tillers per plant, peduncle length, spike weight per plant, grain weight per spike, canopy temperature. However, this interaction was non-significant for other characters, which indicated that genotypes interacted considerably with the environmental condition that existed over different irrigation and sowing situations. However, this interaction was non-significant for characters like spike length, flag leaf length, flag leaf width, 1000 grain weight, yield per plant, biological yield, and harvest index, indicating that these characters under all four environmental conditions had followed a more or less similar pattern. Nine characters *viz.*, tillers per plant, flag leaf length, spike weight per plant, grain weight per spike, thousand-grain weight, yield per plant, canopy temperature, canopy biological yield, harvest index were having highly significant pooled deviation which showed that some portion of G X E was unpredictable. Hence, care should be taken in the selection of genotypes based on stability analysis from the present material. The present findings are in agreement with the result of Singh et al. (2016), Mohammadi et al. (2014), Meena et al. (2014), Kumar et al. (2014), Olgun, et al. (2014), Kota et al. (2013), Ameen (2012), Mahmodi et al. (2011), Tripura et al. (2011), Mohammadi et al. (2011).

Table 1: Stability analysis of variance for yield and its contributing traits under different environment (Pooled over four consecutive years)

Character/source	Total (G X E)	V	E+(G X E)	E(Linear)	G X E (linear)	Pooled Deviation	Pooled Error
Df	79	19	60	1	19	40	80
Days to heading	23.61	80.90**	5.24**	148.66**	4.96*	2.13	3.72
Days to maturity	63.37	10.96**	76.64**	4666.83**	2.48	2.10	1.78
Plant height	114.16	304.16**	53.66**	2112.88**	19.17	19.06	31.69
tillers per plant	1.91	1.60**	1.89**	64.55**	1.47*	0.70*	0.43
spike length	2.82	6.48**	1.59	22.68**	1.72	1.11	1.33
Peduncle length	17.00	46.39**	7.60*	201.89**	4.06	4.57	7.25
Flag leaf length	5.34	8.93**	3.95	81.91**	2.34	3.15*	1.94
Flag leaf width	0.02	0.05**	0.02	0.02	0.02	0.01	0.01
Spike weight per plant	13.04	14.34**	11.46**	352.67**	9.79	5.47**	2.75
Grain weight per spike	0.13	0.09**	0.14**	4.36**	0.10*	0.05*	0.03
1000 grain weight	11.31	20.13**	8.42	78.30**	10.43	5.86**	2.07
Yield/plant	4.95	3.78*	5.29	76.25**	3.17	4.56**	2.15
canopy temperature	1.25	0.72*	1.35**	48.27**	0.45	0.71*	0.34
Biological yield	18.43	30.50*	14.28	106.71*	6.33	16.25**	3.49
Harvest index	13.85	15.34	13.15	163.13**	13.04	9.79**	5.04

*Significant at P=0.05; **Significant at P=0.01

Stability Analysis

Eberhart and Russel (1966) estimate for measuring the stability of genotype considered both linear regression coefficient (b_i) and non-linear, i.e., deviation from regression (S^2d_i) for G×E interaction. Here b_i showed how genotype respond to a different environment and (S^2d_i) measured stability (Paroda and Hayes 1971, Jatsara and Paroda 1980 and Yadav et al. 2009). Genotype, with the lowest deviation from the regression line (S^2d_i), was found to be stable. In order to find superior and stable genotype across varied environmental conditions here, we measured all three components that are high mean performance, regression coefficient (b_i =1), and deviation from regression (S^2d_i=0).

The stability parameter component for 15 characters is shown in table 2 to table 5. These tables revealed that genotypes RVW-4266, RVW-4267, RVW-4268, RVW-4270, RVW-4271 had regression coefficient (bi) nearly one and non-significant mean square deviation with superior mean performance signifying average stability for grain yield and having better performance across all four environments. Genotypes RVW-4261, RVW-4271, RVW-4273, RVW-4274 were seen to be stable with regression coefficient (b_i) value approximately one and non-significant (S^2d_i).

Genotypes RVW-4262, RVW-4263, RVW-4264, RVW-4272, RVW-4275, and RVW-4278 had a regression coefficient more significant than one and deviation from regression mean is non-significant revealing that they are suitable for favorable condition (E2 and E3) and showing average stability. Six genotypes RVW-4265, RVW-4269, RVW-4276, RVW-4277, RVW-4279, and RVW-4280 with higher mean yield had regression coefficient less than one and non-significant mean square deviation indicating that these are stable for the unfavorable environment (E1, E4) and had above-average stability.

Since grain yield is not a character that can be evaluated individually, although it is a complex character that depends on many other characters (Mandariya et al., 2001), hence it is important to analyze its related traits also for better interpretation of results. From table 2 to 5, it was seen that none of the genotypes showed a non-significant regression coefficient for all 15 characters; hence none genotype showed stable performance for 15 characters across a diverse environment.

For grain yield genotype, RVW-4263 showed the highest yield value, followed by RVW-4270, RVW-4271, RVW-4272, RVW-4278, RVW-4273, RVW-4274, and RVW-4261. The high yield of genotype RVW-4263 was associated with high mean values of Days to maturity, plant height, tillers per plant, peduncle length, grain weight/spike 1000 grain weight, biological yield, and harvest index. Likewise, high yield of genotype RVW-4271 resulted from characters days to heading, days to maturity, plant height, tillers per plant flag leaf width, flag leaf length, peduncle length, spike length, canopy temperature, biological yield. Similarly, genotype RVW-4272 had characters days to heading, days to maturity, flag leaf width, spike length, grain weight per spike, biological yield, and harvest index associated with high grain yield. Thus high yield stability of genotype RVW-4270 was the contribution of characters days to maturity, plant height, tillers per plant, flag leaf width, peduncle length, grain weight per spike, and biological yield. Accordingly, the superior yield of genotype RVW-4278, RVW-4273, RVW-4274, and RVW-4261`was associated with the stability of different contributing traits for adaptation across the different environment.

Table 2: Stability parameters of yield and its contributing attributes

		Days to heading			Days to maturity			Plant height			Tillers per plant		
S no	Variety	mean	b_i value	S^2d_i	Mean	b_i value	S^2d_i	mean	b_i value	S^2d_i	Mean	b_i value	S^2d^i
1	RVW-4261	67.25	0.71*	0.78	110.63	0.90**	5.08	106.47	0.94	20.66	6.03	1.14	0.25
2	RVW-4262	63.13	1.03	1.94	109.75	1.07**	0.56	111.59	1.17	-5.06	6.20	2.07**	0.54
3	RVW-4263	66.88	1.67**	0.20	113.13	0.99**	-0.15	116.44	1.56**	3.09	6.30	-0.05**	0.01
4	RVW-4264	65.25	0.57**	0.21	109.50	1.10**	0.67	115.35	1.04	-1.52	5.78	0.93	1.02
5	RVW-4265	80.63	3.18**	0.12	113.50	0.87**	1.47	89.42	0.55**	49.88	5.55	0.07**	1.25*
6	RVW-4266	68.50	1.14	-0.84	109.63	1.12**	2.48	92.87	0.76**	0.68	6.15	1.14	0.12
7	RVW-4267	70.75	-1.28**	2.08	111.38	1.09**	4.10	106.15	1.15	19.57	4.63	0.52**	-0.06
8	RVW-4268	73.75	1.23	7.82	112.13	1.10**	1.35	113.38	1.57**	45.37	6.25	0.15**	0.19
9	RVW-4269	74.38	0.75	4.76	112.75	0.93**	0.91	99.58	0.95	-3.55	6.45	2.09**	0.79
10	RVW-4270	67.13	0.18**	-0.51	111.00	1.17**	-0.09	104.02	1.97**	-0.31	7.48	2.01**	0.75
11	RVW-4271	71.88	1.68**	0.83	111.63	1.08**	4.48	107.93	1.21*	-0.95	6.50	0.33**	1.06
12	RVW-4272	72.13	0.77	7.64	111.13	1.00**	0.58	100.49	1.08	-3.82	6.00	1.24**	0.23
13	RVW-4273	73.75	1.03	-0.55	113.50	0.83**	0.69	109.13	1.03	-7.58	5.75	1.54**	-0.04
14	RVW-4274	63.00	1.11	-0.59	111.63	1.05**	3.12	98.50	1.17	-0.85	6.80	1.02	-0.11
15	RVW-4275	72.00	0.71*	-0.85	113.00	0.93**	4.30	104.80	0.75**	5.47	5.03	0.48**	0.09
16	RVW-4276	63.88	1.12	-0.05	108.75	0.89**	0.13	94.06	0.58**	23.02	6.03	1.10	0.90
17	RVW-4277	72.25	1.17	0.05	109.88	0.86**	0.60	104.07	0.35**	7.16	6.35	1.63**	0.52**
18	RVW-4278	66.00	0.48**	-0.08	109.00	0.98**	0.67	93.25	1.35**	59.07	5.13	0.15**	-0.11
19	RVW-4279	70.50	1.46**	1.30	109.00	1.11**	1.40	87.34	0.41**	26.52	6.20	1.05	0.03
20	RVW-4280	66.63	1.28	-0.22	108.63	0.92**	0.16	92.85	0.42**	-7.72	6.20	1.38**	0.30
	Mean	69.20			110.98			102.38			6.04		
	SE(m)	1.98			1.37			5.78			0.68		
	CD 5%	4.03			2.78			11.76			1.37		

*Significant at P=0.05; **Significant at P=0.01

Table 3: Stability parameters of yield and its contributing attributes

		Spike length			Peduncle length			Flag leaf length			Flag leaf width		
S no	Variety	mean	b_i value	S^2d_i	mean	b_i value	S^2d_i	mean	b_i value	S^2d_i	mean	b_i value	S^2d_i
1	RVW-4261	14.52	1.09	2.16	19.24	1.23	-1.46	25.11	0.24*	2.27	1.96	2.15	0.021
2	RVW-4262	16.40	2.32	-0.08	25.17	1.17	-0.50	21.93	0.29	2.93	1.77	8.81	0.001
3	RVW-4263	14.92	0.50	-0.25	20.89	1.97**	6.42	19.89	-0.21**	2.06	1.66	-1.04	0.004
4	RVW-4264	15.95	1.88	-0.31	27.05	1.29	1.75	23.52	0.94	2.35	1.78	-1.76	0.024
5	RVW-4265	18.57	-0.90**	0.69	14.95	1.27	7.71	24.09	1.48	-0.15	1.73	2.83	-0.002
6	RVW-4266	17.07	-1.09**	-0.15	16.93	1.02	9.08	23.86	2.24**	1.46	1.94	2.37	0.007
7	RVW-4267	16.80	1.21	0.11	16.71	1.08	1.72	23.62	0.34	0.37	1.74	-0.52	0.0001
8	RVW-4268	17.84	1.34	3.61	19.72	-0.90**	1.94	24.81	1.30	1.60	1.76	5.14	0.020
9	RVW-4269	15.05	0.30	-0.11	12.42	1.66**	-1.04	22.76	1.28	3.71	1.93	-0.01	0.016
10	RVW-4270	15.28	1.71	1.22	18.91	1.10	-1.52	23.18	0.22*	0.08	1.96	4.65	0.010
11	RVW-4271	18.70	2.67**	0.65	21.17	1.33	9.56	26.48	0.78	2.05	1.92	-3.33	0.005
12	RVW-4272	16.95	3.32**	2.04	16.04	1.62**	0.40	22.52	1.76*	2.78	1.89	-9.12	0.019
13	RVW-4273	15.58	1.24**	0.61	18.02	0.39**	-1.34	22.57	2.34**	2.08	1.98	2.50	0.014
14	RVW-4274	16.41	-1.12**	-0.12	18.10	1.38	12.65	23.50	0.60	5.34	1.84	-0.02	0.028
15	RVW-4275	14.93	2.04**	0.41	16.41	0.52**	-1.29	21.86	1.11**	7.20	1.87	-1.28	0.022
16	RVW-4276	15.59	-0.05**	0.51	19.63	1.15	3.61	24.18	2.48	2.76	1.76	-5.61	0.002
17	RVW-4277	18.19	-0.14**	0.56	19.10	0.45**	15.94	25.81	0.75	3.70	1.60	0.59	0.00003
18	RVW-4278	17.24	0.56	2.85	16.49	1.28	-0.16	23.87	0.66	0.00	1.81	5.26	-0.001
19	RVW-4279	17.12	1.47	-0.26	14.86	0.85	-1.51	23.61	1.02	0.36	1.72	5.62	0.010
20	RVW-4280	15.46	1.64	0.30	16.78	0.13**	0.74	25.05	0.39	6.87	1.65	2.77	0.001
	Mean	16.43			18.43			23.61			1.81		
	SE(m)	1.18			2.76			1.43			0.11		
	CD 5%	2.41			5.62			2.91			0.22		

*Significant at P=0.05; **Significant at P=0.01

Table 4: Stability parameters of yield and its contributing attributes

		Spike weight per plant			Grain weight per spike			1000 grain weight			Yield/plant		
S no	Variety	mean	b_i value	S^2d_i	mean	b_i value	S^2d_i	mean	b_i value	S^2d_i	mean	b_i value	S^2d_i
1	RVW-4261	23.79	0.47**	2.14	1.93	1.82**	-0.01	38.96	2.52*	1.97	14.07	0.93	1.03
2	RVW-4262	18.70	0.69*	3.25	2.06	2.26**	0.02	40.38	0.41	1.04	13.68	1.60	6.39*
3	RVW-4263	19.95	0.23	0.73	2.05	0.26**	0.04	40.80	1.60	1.84	15.62	1.71	11.46**
4	RVW-4264	18.10	0.57**	2.53	1.92	0.62**	0.004	41.30	1.04	-0.30	12.65	1.81	1.00
5	RVW-4265	19.92	-0.09**	-0.70	1.65	1.62**	0.02	38.09	3.60**	-0.41	13.07	-0.10	2.83
6	RVW-4266	21.17	0.68**	3.40	1.94	0.49**	0.01	36.55	1.74	0.78	12.95	0.64	0.82
7	RVW-4267	19.56	1.69**	6.35	1.77	1.38**	0.01	35.75	0.77	8.36*	13.22	0.74	5.76
8	RVW-4268	17.08	0.89	10.59*	1.71	-0.23**	0.01	37.35	-0.97**	4.08	13.39	0.56	7.36*
9	RVW-4269	18.91	0.44**	18.06**	1.85	2.19**	0.04	40.13	2.02	4.60	14.61	-0.28**	16.60**
10	RVW-4270	19.17	1.10	3.13	1.86	1.04	0.15**	36.36	1.69	7.53*	15.19	1.58	9.81**
11	RVW-4271	19.72	1.56**	19.89**	1.75	0.07**	-0.002	33.11	0.43	0.36	15.10	1.11	5.10
12	RVW-4272	17.79	0.64**	-0.16	1.93	0.62**	0.17**	36.46	-0.22	25.40**	14.96	3.35**	3.99
13	RVW-4273	21.02	1.36**	4.68	1.82	0.62**	0.03	34.50	2.98**	9.19*	14.67	1.22	0.77
14	RVW-4274	20.28	2.72**	7.49	1.66	0.64**	0.27**	35.63	1.42	0.41	14.34	1.07	0.95
15	RVW-4275	21.33	0.60**	1.91	1.86	1.70**	0.005	35.54	-2.24**	4.51	12.30	0.60	-0.47
16	RVW-4276	20.20	0.18**	-0.52	1.73	0.98	0.06	35.70	2.94**	17.06**	12.62	0.18	2.55
17	RVW-4277	21.45	1.16	3.02	1.52	1.51**	0.00001	37.30	2.64**	4.38*	13.43	0.35	1.69
18	RVW-4278	24.55	2.43**	6.19	1.70	0.66**	0.08	38.29	-0.72**	9.63**	14.68	2.57**	1.29
19	RVW-4279	17.60	0.76	0.32	1.83	1.01	0.01	34.88	-1.93**	0.79	13.22	0.18	0.28
20	RVW-4280	20.15	1.90**	2.28	1.55	0.73**	-0.004	38.44	0.30	1.91	13.65	0.18	-0.03
	Mean	20.02			1.80			37.28			13.87		
	SE(m)	1.70			0.18			1.48			1.51		
	CD 5%	3.46			0.37			3.01			3.07		

*Significant at P=0.05; **Significant at P=0.01

Table 5: Stability parameters of yield and its contributing attributes

		Canopy temperature			Biological yield			Harvest index		
S no	Variety	mean	b_i value	S^2d_i	mean	b_i value	S^2d_i	Mean	b_i value	S^2d_i
1	RVW-4261	22.37	0.15**	1.55**	39.66	0.55	35.04**	35.39	0.36	0.21
2	RVW-4262	22.39	1.52**	0.11	36.26	1.65	28.65**	35.84	1.02	-0.64
3	RVW-4263	21.99	1.29	0.20	40.31	3.46	16.84**	41.35	-0.88**	26.35**
4	RVW-4264	22.28	0.39**	0.84	38.37	2.11	2.06	38.99	0.96	9.12
5	RVW-4265	22.03	1.13	0.80	37.07	1.10	58.63**	40.19	2.14	15.46*
6	RVW-4266	21.78	0.84	0.16	34.37	1.57	16.79**	38.86	0.29	2.56
7	RVW-4267	21.30	0.32**	0.70	35.99	0.50	11.88*	38.12	1.93	-0.07
8	RVW-4268	23.37	1.86**	1.81**	33.96	-0.01	10.14*	35.32	-0.21*	-1.31
9	RVW-4269	22.11	1.34**	0.95*	41.42	0.48	50.55**	35.52	1.40	7.03
10	RVW-4270	22.11	0.61**	0.60	38.96	1.13	2.65	34.97	1.17	1.16
11	RVW-4271	22.30	1.24	0.77	39.08	1.06	2.85	36.04	0.61	1.03
12	RVW-4272	21.87	1.39**	0.97*	39.93	2.46	9.26	41.32	3.67**	14.91*
13	RVW-4273	22.39	0.98	0.30	41.82	-0.99	1.87	37.62	-0.38**	-0.10
14	RVW-4274	21.95	0.88	-0.07	38.59	0.62	17.01**	36.68	1.87	12.97
15	RVW-4275	22.05	1.31**	0.41	37.34	1.12	19.91**	38.28	-1.31**	22.59*
16	RVW-4276	22.62	0.89	2.08**	35.39	1.90	3.81	38.68	2.54**	16.75*
17	RVW-4277	21.65	0.84	0.01	38.18	-0.89	0.23	38.21	2.73**	5.90
18	RVW-4278	21.86	0.63**	0.04	33.91	0.07	-0.66	39.11	1.51	6.04
19	RVW-4279	22.11	1.09	0.07	32.14	0.28	19.66**	38.59	0.59	26.56**
20	RVW-4280	22.53	1.30*	0.02	33.83	1.82	0.32	36.17	0.0005	5.53
	Mean	22.33			37.33			37.76		
	SE(m)	0.60			1.92			2.30		
	CD 5%	1.22			3.90			4.69		

*Significant at P=0.05; **Significant at P=0.01

Environmental indices comparison

Table 6 shows that timely sown partially irrigated condition (E2), irrigated late sown condition (E3) were found favorable for most of the characters except for 1000 grain weight and canopy temperature. Environmental indices indicated that the performance of genotypes over four environments with respect to the grain yield varied apparently and indicated that irrigated late sown condition (E3) and timely sown partially irrigated condition (E2) showed the highest favorable impact on grain yield. Similarly, biological yield under E3 and E2 was found to be on the higher side with 1000 grain weight, spike weight per plant, and spike length. Moreover, the early maturity of genotypes under E3 might also be contributed towards higher grain yield by minimizing the adverse impact of terminal heat as indicated by reduced days to heading. Therefore, it appears that under favorable environments, the grain yield invariably associated with the early heading, biological yield, 1000 grain weight, spike weight per plant, and spike length. The extent of flag leaf traits, *viz.* length and width also support the performance in respect of the grain yield. Environment E4 followed by E1 was found to be unfavorable in terms of grain yield, where most of the significant yield contributing traits, *viz.* biological yield, and 1000 grain weight, spike weight per plant, and spike length were in the lower side as indicated by negative values of environmental indices. Environment E1 was found unfavorable due to fluctuating higher temperatures. Mean performance for grain yield and other contributing traits under unfavorable environment E4 and E1 was although low. A similar finding in wheat was reported by Singh and Chaudhary (2007) and Gowda et al. (2010).

Table 6: Effect of the environment in the expression of yield and its contributing traits (Environmental indices)

Characters	E1	E2	E3	E4
Days to heading	0.84	1.79	-1.21	-1.43
Days to maturity	5.85	8.85	-4.82	-9.88
Plant height	-0.23	5.93	2.35	-8.05
Tillers per plant	1.43	-0.09	-0.30	-1.04
spike length	0.01	0.70	0.08	-0.80
Peduncle length	-0.19	1.17	1.53	-2.52
Flag leaf length	-0.20	-1.52	1.22	0.50
Flag leaf width	-0.02	0.03	-0.001	-0.01
Spike weight per plant	-1.73	0.37	3.29	-1.93
Grain weight per spike	0.19	0.25	-0.13	-0.32
1000 grain weight	1.29	0.15	0.05	-1.49
Yield/plant	-0.42	0.49	1.26	-1.34
canopy temperature	-0.55	-0.68	-0.06	1.28
Biological yield	-1.05	0.92	1.36	-1.24
Harvest index	1.18	1.49	-0.64	-2.03

E1- Timely sown irrigated, **E2-** Timely sown partially irrigated, **E3-** Late sown irrigated, **E4-** Late sown partially irrigated

Finlay and Wilkinson (1963) considered the linear regression as a measure of stability. Eberhart and Russell (1966) suggested that linear regression is a measure of response and emphasized the need to consider linear and non-linear components of genotype-environment interaction in determining stability. In the present study, mean performance, regression coefficient, and deviation from regression have been considered together for judging the stability of genotypes in wheat. High grain yield was recorded for genotype RVW-4271 followed by RVW-4173, RVW-4274, RVW-4261, RVW-4280, RVW-4277, RVW-4267, RVW-4279, RVW-4265, RVW-4266, RVW-4264 and RVW-4276. All these genotypes showed an average response and wider adaptation as they were found stable in all four environments with non- significant regression coefficient (b_i) and non- significant deviation from regression (S^2d_i). Thus, exhibiting wider adaptability under timely sown irrigated condition (E1), timely sown partially irrigated condition (E2), irrigated late sown condition (E3), partially irrigated late sown condition (E4). These genotypes can be useful for wider varying situations and maybe use as parents in the future breeding program. Genotypes, RVW-4272, and RVW-4278 were found responsive to favorable conditions and stable having regression coefficient (b_i) significantly positive and non-significant deviation from regression (S^2d_i) with better yield. Genotypes RVW-4269 showed comparatively high yield, responsive to the poor environment, but it was found unstable, having a negative Estimate of the regression coefficient (b_i) and significant deviation from regression (S^2d_i). This genotype may be utilized as parents in wheat breeding programs in order to transfer stability of better performance in poor environments. Genotype RVW-4162, RVW-4263, RVW-4268, RVW-4270 showed an average response and higher yield but were found unstable, having significant deviation from regression (S^2d_i). The present findings are in agreement with the result of Mohammadi et al. (2014), Meena et al. (2014), Kumar et al. (2014), Olgun, et al. (2014), Kota et al. (2013), Ameen

(2012), Mahammadi et al. (2011), Tripura et al. (2011), Singh et al. (2016).

Responsiveness and stability in grain yield were found associated with stability and responsiveness in yield attributes. An overall observation of stability analysis revealed that genotype RVW-4271, followed by RVW-4273, RVW-4274, RVW-4261, RVW-4280, appeared as promising genotype having comparatively high yield, average responsiveness showing stable performance with wider adaptation under all environment. These genotypes can be advanced in testing and may be used in future breeding strategies. Stable performance of genotype RVW-4271 was found associated with the stable performance of all yield contributing traits, and its average response was found associated with flag leaf length, flag leaf width, 1000 grain weight, canopy temperature, biological yield, and harvest index. Stable performance of genotype RVW-4273 was found associated with the stable performance of all yield contributing trait except for 1000 grain weight. The average response was found associated with days to heading, flag leaf width, canopy temperature, biological yield Stable performance of genotype RVW-4274 was found associated with the stable performance of all yield contributing trait except for grain weight per spike and the biological yield on the other hand average response was found associated with days to heading, tillers per plant flag leaf width, flag leaf length, 1000 grain weight, canopy temperature, biological yield and harvest index Stable performance of genotype RVW-4261 was found associated with the stable performance of all yield contributing trait except for canopy temperature and the biological yield on the other hand average response was found associated to tillers per plant, spike length, flag leaf width, biological yield, and harvest index. Stable performance of genotype RVW-4280 was found associated with the stable performance of all yield contributing traits, on the other hand, the average response was seen related to days to heading, spike length, flag leaf length, flag leaf width, 1000 grain weight, biological yield, and harvest index.

CONCLUSION

The variance due to the environment was highly significant for all characters except flag leaf width. The genotypic variance was significant for all traits. The variance due to G X E interaction (linear) was highly significant for days to heading, tillers per plant, grain weight per spike. Mean sum of square due to E + (V X E) interaction was highly significant for days to heading, days to maturity, tillers per plant, spike weight per plant, grain weight per spike, canopy temperature. Nine characters had significant pooled deviation.

Grain yield was recorded highest for RVW-4271 followed by RVW-4273, RVW-4274, RVW-4261, RVW-4280, RVW-4277, RVW-4267, RVW-4279, RVW-4265, RVW-4266, RVW-4264 and RVW-4276. Genotypes, RVW-4272, and RVW-4278 were found stable and responsive in favorable conditions. Genotypes RVW-4269 showed comparatively high yield and were responsive to the poor environment. Still, it was found unstable, having a negative Estimate of the regression coefficient (b_i) and significant deviation from regression (S^2d_i). Responsiveness and stability for grain yield also associated with stability and responsiveness in most of the yield attributes

Genotype RVW-4271, RVW-4173, RVW-4274, RVW-4261, RVW-4280 appeared as promising genotype having comparatively high yield, average responsiveness showing stable performance with wider adaptation under all environment. These genotypes can be advanced in testing and may be used in the future breeding strategy.

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