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Stability analysis for late sown bread wheat (*Triticum aestivum* L.)

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Abstract
The present experiment was conducted with 11 bread wheat genotypes along with three standard checks in RBD with three replications at three locations. The variance due to genotypes were found highly significant when tested against G × E interaction, pooled deviation and pooled error for all the characters *viz.*, days to 50% heading, days to maturity, plant height (cm), number of tillers per plant, thousand grain weight (g) and grain yield per plot (kg). Mean Sum of Square (MSS) due to environment were significant for all characters except number of tillers per plant and thousand grain weight (g) when tested against G × E interaction, pooled deviation and pooled error. G × E interaction was found significant for all the characters studied except thousand grain weight (g) when tested against pooled error. Check Phule Samadhan and check NIAW 34 recorded average stability for days to 50% heading. The genotype NIAW 3923 exhibited average stability for days to maturity. Check NIAW 34 exhibited average stability for plant height and the genotype NIAW 3923, check Phule Samadhan and check NIAW 34 exhibited average stability for number of tillers per plant indicating their stability for all environment.

Keywords: Wheat, stability analysis, G × E interaction, Eberhart and Russell (1966) [5] model

Introduction
Wheat (*Triticum aestivum* L.) is a self-pollinated crop originated in South-Western Asia, is considered as the second leading cereal crop in the world after rice. Wheat occupies the prime position among the food crops in the world. Wheat has been described as the ‘King of cereals’ because of the acreage it occupies, noticeable position it holds in the international food grain trade with high productivity. The crop grows best in temperate climates, but it is also cultivated and consumed in the tropical and sub-tropical regions.
In terms of area and production, China ranks first and India ranks second among wheat growing countries. India contributes approximately about 30% of total food grain production. It was cultivated on 217 mha in the world, yielding 731 million tonnes (Anonymous, 2019) [1] and on 30.56 mha in India, yielding 109.24 million tonnes (Anonymous, 2020) [2]. Uttar Pradesh, Punjab, Haryana, Rajasthan, Bihar, Madhya Pradesh, Gujarat, Maharashtra and Karnataka are the major wheat growing states of India.
Due to increasing population of the world and changing food habits, the demand for wheat by 2050 is predicted to be increased by 70 per cent. The cultivation of wheat crop is also facing additional challenges and is at risk due to more aggressive pests and diseases; limited availability of land, diminishing water resources and unstable weather conditions primarily due to climate change such as global warming. Time has come to concentrate on stress tolerance to grab further chances of increasing production and productivity of wheat crop to feed increasing population. To achieve the set target of production, it is necessary to identify stable genotypes for yield which will perform better under different and changing climatic conditions. Agriculture sector is most affecting sector to climate change. Indian agriculture is characterized by diverse crops and prevailing climatic conditions. The predicted climatic change and impacts associated with climatic change are likely to be adversely affect the sustainability and potential of agriculture. Therefore, genotypes which are stable under changing temperature and fluctuating climatic conditions are desirable, for this, present investigation entitled, “Stability analysis for late sown bread wheat (*Triticum aestivum* L.)” was undertaken.

Material and methods
The experimental material for the present study consisted of 11 genotypes of bread wheat (*Triticum aestivum* L.) along with three standard checks *viz.*, Phule Samadhan, NIAW 34 and

HD 2932 procured from Agricultural Research Station, Niphad, Dist. Nashik-422 303 (M.S.) India. Experiment was conducted in Randomised Block Design (RBD) with three replications at three locations *viz*., Post Graduate Institute Farm, MPKV, Rahuri, Agricultural Research Station, Niphad and Agricultural Research Station, Savalivihir during Rabi, 2019-20. To raise a good crop, the rest of the recommended package of practices were followed. Observations were recorded for 6 quantitative characters. The characters were days to 50% heading, days to maturity, plant height (cm), number of tillers per plant, 1000 grain weight (g) and grain yield per plot (kg).

The data collected were subjected for testing the genotypic differences (Panse and Sukhatme, 1967) for Randomised Block Design (RBD). Stability analysis was performed by utilizing methods proposed by Eberhart and Russell (1966) [5]. For each genotype stability was described by three parameters *viz*., mean performance ($\bar{X}$), regression coefficient (bi) and the squared deviation from the regression (S^2di).

These parameters are defined by using the following model.

$$Y_{ij} = \mu + \beta_i I_j + \delta_{ij} \quad (I= 1, 2 \ldots\ldots, t \text{ and } j = 1, 2 \ldots\ldots s)$$

Where,

Yij = Mean of ith genotype in jth environment.

μ = Mean of all genotypes over all environments.

Bi = The regression coefficient of ith genotype on the environmental index, which measures response of genotype to varying environments.

Ij = The environmental index which is defined as deviation of the mean of all the genotypes at a given environment from the overall mean.

$$\frac{\sum_j Y_{ij}}{T} - \frac{\sum_i \sum_j Y_{ij}}{ts} \text{ with } \sum I_j = 0$$

Δij = The deviation from regression of the ith genotype of jth environment.

Stability Parameters

a. The regression coefficient (bi) is calculated as under

$$b_i = \sum_j Y_{ij} I_j / \sum_j I^2_j$$

Where,

$\sum_j Y_{ij} I_j$ is the sum of products

$\sum_j I^2_j$ is the sum of squares of environmental index

b. Mean square deviation (S^2di) from linear regression is calculated as

$$S^2di = \frac{\sum_j \delta^2_{ij}}{(s-2)} - \frac{S^2e}{r}$$

Where,

$$\sum_j \delta^2_{ij} = \left(\sum_j Y^2_{ij} - \frac{Y^2_i}{t} \right) - \frac{(\sum_j Y_{ij} . I_j)^2}{\sum_j I_j}$$

S^2e = The estimate of pooled error

t = Number of genotypes

s = Number of environments

Analysis of Variance

The analysis of variance partitioned into three main parts

a. Sum of squares due to genotypes.
b. Sum of squares due to environment + (genotype × environment)
c. Pooled error

The sum of squares due to genotype × environment is further partitioned into two parts.

i. S.S. due to genotype ×environment (linear) which is in fact S.S. due to regression.
ii. S.S. due to deviation from linearity of response (i.e., S.S. due to pooled deviation).

The latter can be further partitioned into as many components as the number of genotypes with (s-2) degrees of freedom (s represents number of environments).

Test of Significance

a) The significance of difference among genotypes were tested against the M.S.S. due to G × E interaction. The genotypic differences were also tested against pooled deviation and pooled error.
b) The G × E interaction was tested against effective pooled error.
c) The components, environment (linear) as well as G × E (linear) was tested against pooled deviation and pooled error.
d) Pooled deviation was tested against effective pooled error (PE/r).

Results and discussion

Analysis of variance representing the mean sum of squares (M.S.S.) due to different sources of variation as per Eberhart and Russell (1966) [5] model for six characters is presented in Table 1. Pooled analysis of variance over three different locations showed that genotypes differed significantly for all the characters *viz.*, days to 50% heading, days to maturity, plant height, number of tillers per plant, thousand grain weight (g) and grain yield per plot (kg) when tested against G × E interaction, pooled deviation and pooled error indicating the presence of variability in the studied material. Similarly, environments in which genotypes were grown also differed significantly for the characters *viz.*, days to 50% heading, days to maturity, plant height and grain yield per plot when tested against G × E interaction, pooled deviation and pooled error indicating sufficient amount of environment-to-environment variability. Earlier Bains and Gupta (1972) [4], Krupal (2017) [8] and Rathod (2018) [11] also reported significant differences between genotype and environment for major characters under study in wheat.

Variance due to G × E interaction was found significant for days to 50% heading, days to maturity, plant height, number of tillers per plant and grain yield per plot traits when tested against pooled error. It was also found significant for days to maturity when tested against pooled error. This indicated differential response of genotypes in expression of character to varying environments. But in character thousand grain weight insignificant G × E interaction found when tested against pooled error and pooled deviation indicated that stability for this character could not performed. Earlier Bains and Gupta (1972) [4], Kishor *et al.* (1992) [7], Yadav and Choudhari (2004) [12], Gowda *et al.* (2010) [6], Polat *et al.* (2016) [10], Krupal (2017) [8] and Rathod (2018) [11] reported significant G × E interaction for most of the character under study in wheat.

Partitioning of G × E interaction showed that G × E (linear) effect was significant for the characters *viz*., days to 50% heading, days to maturity, plant height, number of tillers per plant and grain yield per plot when tested against pooled error. However, days to maturity and plant height traits found significant when tested against pooled deviation indicating the predictability of the performance of genotypes over environments.

Both linear and non-linear components of G × E interactions were significant for all the characters except thousand grain weight indicating that genotypes responded linearly to environmental changes in respect of these characters. Researchers like Bains and Gupta (1972) [4], Kishor *et al.* (1992) [7], Mehta *et al.* (2000) [9], Ashraf *et al*. (2001) [3] and Rathod (2018) [11] reported the significant linear and non-linear components of G × E interactions for most of the characters under study in wheat.

Environment (linear) effect was significant for the traits *viz*., days to 50% heading, days to maturity, plant height and grain yield per plot when tested against pooled deviation and pooled error. While character thousand grain weight found significant when tested against pooled error. Kishor *et al.* (1992) [7] also reported significant environment (linear) effects for most of the traits in wheat.

Stability parameters of genotypes presented in table no 2. The check Phule Samadhan and check NIAW-34 recorded average stability for days to 50% heading. The genotype NIAW-3923 exhibited average stability for days to maturity. Check NIAW-34 showed average stability for plant height and the genotype NIAW-3923, check Phule Samadhan and check NIAW-34 exhibited average stability for number of tillers per plant. Above average stability was observed for genotypes NIAW-3931 and NIAW-3944 for days to 50% heading, Check NIAW-34 for days to maturity while, genotypes NIAW-3927, NIAW-3947 and check Phule Samadhan for plant height indicating their suitability for poor or stress environments. Below average stability was observed for genotype NIAW-3947 for days to 50% heading; NIAW-3980 for days to maturity; genotypes NIAW-3942, NIAW-3980 and check HD-2932 for plant height as well as genotypes NIAW-3923 and NIAW-4028 for grain yield per plot indicating their suitability for rich or favourable environments. None of the genotype was found stable for all the characters under study.

Conclusion

Linear and non-linear component of G × E interactions were found significant for all characters under study except thousand grain weight. None of the genotype was found average stable for all the characters. The genotypes under study showed differential stability performance for all the characters except thousand grain weight. The released varieties NIAW-34 and Phule Samadhan showed average stable performance for most of the characters.

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Table 1: ANOVA for stability as per Eberhart and Russell Model (1966) [5] in wheat

Sr. No.	Sources	G	E	G × E	E+G × E	E (L)	G × E (L)	P.D. (Pooled deviation)	P.E. (Pooled error)
1	Degrees of freedom	13	2	26	28	1	13	14	78
2	Days to 50 per cent heading	7.51++**##	21.05++**##	1.66##	3.05##	42.11**##	1.65##	1.56##	0.12
3	Days to maturity	20.05++**##	48.38++**##	4.75*##	7.87**##	96.76**##	7.70**##	1.68##	0.22
4	Plant height (cm)	42.20++**##	103.05++**##	2.10#	9.31**##	206.11**##	3.10*##	1.01	1.24
5	Number of tillers per plant	7.26++**##	0.07	1.35##	1.26##	0.15	1.40##	1.21##	0.18
6	Thousand grain weight (g)	16.96++**##	0.91	0.44	0.47#	1.82#	0.19	0.63#	0.29
7	Grain yield per plot (kg)	0.74++**##	3.93++**##	0.05#	0.33**##	7.86**##	0.07#	0.04	0.03

+, ++ : Significant at 5 and 1 % level of significance, respectively against G × E

*, ** : Significant at 5 and 1% level of significance, respectively against the pooled deviation (PD)

#, ## : Significant at 5 and 1% level of significance, respectively against the pooled error (PE)

Table 2: Estimates of stability parameters for six characters

Sr. No.	Genotypes	Days to 50 per cent heading			Days to maturity			Plant height (cm)		
		$\overline{X}$	bi	S^2di	$\overline{X}$	Bi	S^2di	$\overline{X}$	bi	S^2di
1	NIAW- 3923	55.88	1.20	2.22**	103.88	0.44	0.49	100.64	1.70**	-0.89
2	NIAW- 3927	56.44	0.94	0.83**	105.88	1.28	3.78**	93.80	0.73**	-0.77
3	NIAW- 3931	58.44	0.67**	-0.10	108.22	1.51*	1.85**	98.52	1.18**	0.15
4	NIAW- 3942	59.66	1.22**	0.01	108.88	1.36**	-0.19	91.81	1.22**	-0.17
5	NIAW- 3944	57.22	0.40**	-0.11	108.88	1.56**	0.76**	96.13	0.73	0.50
6	NIAW- 3947	58.44	1.22**	-0.09	110.88	1.78**	-0.03	94.38	0.90**	-0.17
7	NIAW-3971	59.11	0.01	1.05**	111.66	1.09*	0.99**	98.40	0.21*	-1.15
8	NIAW- 3975	60.55	1.62**	-0.02	110.88	2.18**	-0.16	96.46	0.94**	-0.89
9	NIAW- 3980	59.66	1.75*	1.50**	108.00	1.06**	0.13	92.40	1.48**	-0.67
10	NIAW- 4028	60.77	0.67**	-0.10	110.00	-0.19	1.07**	98.70	1.36**	-0.72
11	NIAW- 4033	60.22	2.83**	2.36**	111.33	2.78	1.25**	98.83	0.89**	-1.14
12	Phule Samadhan - (C)	57.66	0.14	0.03	106.33	0.20	3.04**	87.06	0.25**	-1.23
13	NIAW- 34- (C)	58.77	0.41	0.32	106.22	0.25**	-0.13	91.44	0.73	1.56
14	HD 2932- (C)	60.77	0.85	12.22**	112.77	-1.35	7.59**	93.83	1.62**	2.48
Mean		58.83			108.85			95.17		
SE ±		0.88	0.72		0.92	0.49		0.71	0.26	

Table 2: Cont…

Sr. No.	Genotypes	Number of tillers per plant			Grain yield per plot (kg)		
		$\overline{X}$	bi	S^2di	$\overline{X}$	bi	S^2di
1	NIAW- 3923	10.04	3.01	0.06	2.42	1.56*	0.11
2	NIAW- 3927	7.31	1.52	-0.02	2.13	0.74*	0.01
3	NIAW- 3931	6.91	-0.21	0.19	1.58	0.12	-0.01
4	NIAW- 3942	10.22	19.87	4.54**	1.83	0.80**	-0.00
5	NIAW- 3944	10.61	-3.62	0.74**	1.95	1.20**	-0.03
6	NIAW- 3947	9.57	-10.79	1.01**	2.09	1.14**	-0.02
7	NIAW-3971	8.03	-4.50	2.91**	1.74	1.12**	-0.03
8	NIAW- 3975	9.61	21.02	3.71**	2.17	1.41**	-0.03
9	NIAW- 3980	12.30	17.62	0.74**	2.17	0.83**	-0.00
10	NIAW- 4028	7.70	-2.47	0.26	3.12	1.10**	-0.03
11	NIAW- 4033	8.92	-2.12	0.22	1.69	0.78**	-0.02
12	Phule Samadhan - (C)	11.14	1.92	0.20	3.32	0.83	0.13*
13	NIAW- 34- (C)	9.31	-13.84	0.04	2.13	1.10**	-0.03
14	HD 2932- (C)	7.94	-13.40	-0.13	2.11	1.21**	0.03
Mean		9.26			2.18		
SE ±		0.78	10.56		0.14	0.27	

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