Stability analysis in wheat(*Triticum aestivum* L.) genotypes under different Environmental Conditions

ABSTRACT

This investigation aimed to assess the interactions between G X E and identify stable genotypes for yield traits in wheat. They conducted the experiment with 30 different wheat genotypes using a Randomized Complete Block Design (RCBD) with two replications. Additionally, they planted the wheat genotypes on three different sowing dates at the ZARS farm college of Agriculture Powarkheda, JNKVV, Jabalpur during the *Rabi* Season of 2022-2023.The analysis of variance was performed on 13 different quantitative traits, both individually and pooled over different environmental conditions. The stability analysis, specifically for grain yield per plant, was carried out using Eberhart and Russell's model. The results showed significant variations among different genotypes and environmental conditions. This indicates that the performance of the wheat genotypes was influenced by both their genetic constitute and the specific growing conditions.The analysis revealed that the mean squares associated with both environmental factors and genotype-environment interactions (E + G x E) demonstrated significant interactions between the genotypes and environments in which they were grown. Furthermore, they found that the partitioning of G X E (linear) interactions was highly significant for grain yield per plant. This suggests that the choice of genotype can significantly impact the yield of wheat in different environmental conditions. Based on the findings, two genotypes GW 322 and MP 3336 were identified as ideal and stable genotypes for grain yield per plant. These genotypes exhibited a mean value higher than the population mean, a regression coefficient close to unity (Bi=1), and minimal deviation from regression (S^2di~0). These stable genotypes can be recommended for cultivation in various seasons and different growing regions, as they are likely to consistently perform well and produce stable yields under different environmental conditions. These identified genotypes can be used to improve wheat cultivation and achieve reliable production.

Keywords: Stability; Eberhart & Russell model; Stable Genotypes; Wheat.

1. INTRODUCTION

Wheat stands as a crucial annual cereal crop globally and holds a significant position in Indian agriculture, ranking just after rice. Among the 17 wheat species, only three are predominantly cultivated worldwide *Triticum aestivum,Triticum durum* and *Triticum dicoccum.* Wheat is widely grown as a primary grain in the cereal category and contributes approximately 30% to the nation's food supply. There is a pressing need for substantial progress in wheat production, not only to meet the ever-growing domestic food demand but also to bolster exports and earn foreign currency.

Wheat stands out favorably in terms of its nutritional composition when compared to other cereals. It boasts an impressive nutritional profile, consisting of 12.1% protein, 1.8% lipids, 1.8% ash, 2.0% reducing sugars, 6.7% pentoses, and a substantial 59.2% starch content. Moreover, it is rich in carbohydrates, with a total carbohydrate content of 70%, providing a significant energy value of 314 kilocalories per 100 grams of food. Additionally, wheat serves as a valuable source of essential minerals and vitamins, including calcium at 37 milligrams per 100 grams, iron at 4.1 milligrams per 100 grams, thiamine at 0.45 milligrams per 100 grams, riboflavin at 0.13 milligrams per 100 grams, and nicotinic acid at 5.4 milligrams per 100 grams, as documented by Lorenz and Kulp in 1991 [1].

Wheat cultivation exhibits versatility, thriving in a range of environmental conditions, including mild, humid to arid, and cold climates. Its cultivation varies from irrigated to rainfed, encompassing regions with high rainfall.The performance of genotypes in terms of yield potential is significantly influenced by various uncontrollable environmental factors, such as location-specific effects and seasonal fluctuations, as well as their interactions. To assess the impact of these environmental factors on crop response, a common approach is to conduct experiments across multiple locations within a single year or across different crop seasons at a single location, or sometimes both (Gauch and Zobel, 1996) [2]. Since grain yield is a complex quantitative trait, it is heavily shaped by the surrounding environment. The Genotype x Environment interaction poses a significant challenge for plant breeders and complicates the recommendation of cultivars due to the inconsistency of top-performing genotypes across various growing conditions. However, it also presents an opportunity to increase yields by cultivating genotypes specifically adapted to particular regions (Kumaresan and Nadarajan, 2010) [3]. Achieving a substantial increase in yield can be realized through the development of a genotype that consistently performs exceptionally well across all environments. Therefore, investigating genotype x environment interaction using appropriate biometric techniques can successfully identify stable genotypes, which can then be considered for commercial cultivation or incorporated into future breeding programs.

One of the primary goals of most breeding programs is to develop cultivars that offer both high and consistent yields, along with desirable yield-related traits. Breeders need to determine whether a particular cultivar is better suited to specific environmental conditions and whether its performance remains consistent when compared to other cultivars. Having predictable performance across a wide range of conditions is advantageous for farmers and seed producers because it extends the adaptability of the cultivar, enhances uniformity, and increases potential sales. As a result, potential cultivars are systematically evaluated across various locations or growing seasons to gauge their adaptability.

The challenge in this context lies in the phenomenon known as Genotype by Environment interaction (GXE), which plays a significant role in the development, testing, and release of cultivars. GXE interaction occurs when the performance of different genotypes varies across different environments. Dealing with GXE interaction and trying to reduce its impact is particularly challenging, especially in regions characterized by extensive climatic variations.

2. MATERIAL AND METHODS

The experiment was carried out on the site of ZARS farm collage of Agriculture Powarkheda, JNKVV, Jabalpur (M.P.) during *Rabi* season 2022-23. Experimental material consisted of 30 wheat genotypes including three checks obtained from AICRP on wheat and barley, College of Agriculture, Powarkheda. The experiment was laid out in Randomized Complete Block Design (RCBD) in two replications along with three different dates of sowing (8^{th} November 2022 – (normal), 18^{th} November 2022 – (late) and 28^{th} November 2023 – (extra late). All the genotypes were sown in four rows pattern keeping 20.0 cm row to row distance. A total of 13 morphological traits based observations were made. Further, observations for days to fifty percent heading, days to maturity, plant height, number of tillers per plant, spike length, spike weight, peduncle length, number of spikelets per spike, number of grain per spike, thousand grain weight, biological yield per plant, harvest index and grain yield per plant were recorded each of the three environments individually and pooled environments. The observations based on mean of the five individual plants was statistically analyzed to find out stability present in the experimental material for each traits especially for yield. The stability analysis was done as per Eberhart and Russell (1966) [4] model.

3. RESULTS

The examination of variance, as outlined in Table 1, offered a comprehensive overview of the variability in performance among the 30 wheat genotypes being studied. The data unveiled statistically significant variations among these genotypes for a range of traits that influence yield. These traits encompassed the time it takes for fifty of the plants to head, the time it takes for the plants to mature, the height of the plants, the number of tillers per plant, the length of the spike, the weight of the spike, the length of the peduncle, the number of spikelets per spike, the number of grains per spike, the yield per plant, the index of harvest, the weight of a thousand grains, and the yield of grain per plant. The extent of these variations underscores the existence of genetic diversity within the studied wheat genotypes.

Furthermore, the interaction between genotype and environment was found to be significant for all traits, indicating that the environmental conditions had a substantial impact on trait expression. This interaction was not only nominal but also exhibited a significant linear component across all traits. This discovery is particularly noteworthy as it suggests that the genotypes' responses to environmental variations were consistent and predictable, which is a crucial aspect for breeders and farmers.

Table 2 expanded on these findings by examining stability parameters for the yield of seeds per plant and its contributing traits across the genotypes. In this analysis, genotypes GW 322 and MP 3336 stood out as exemplary and consistent for grain yield per plant. They were characterized by mean values surpassing the overall mean, regression coefficients (Bi values) approximating unity, and minimal deviation from regression (S^2di~0), indicating their reliable performance across different environments. In contrast, genotypes like CG 1029, GW 3211, and MP 4010, while stable, had mean values below the general mean. Additionally, genotypes such as WAPD 1505, HI 1634, and DBW 71, with regression coefficients lower than unity and minimal deviation from regression, exhibited a tendency for stability in less favorable environments. The remaining genotypes displayed varied responses, as evidenced by deviations in S^2di values and Bi values, indicating their differential stability for seed yield per plant.

4. DISCUSSION

The marked disparities among genotypes for crucial yield characteristics and the noteworthy interplay between genotype and environment emphasize the intricate function environmental factors have in agronomic achievement. This corresponds to the findings of Sharma *et al.* (2010) [5], who observed similar effects of environmental conditions on grain production. The study's outcomes validate the extensive body of research indicating the complexity of wheat breeding, where the selection of genotypes with consistent and high yields across diverse environmental conditions remains a vital yet arduous pursuit.

The identification of specific genotypes such as GW 322 and MP 3336 as both exemplary and steadfast across various environments is a pivotal discovery. This implies the potential of these genotypes for dependable performance, aligning with the investigations conducted by Singh *et al.* (2012) [11] and Sharma *et al.* (2019) [13], which identified comparable patterns in grain yield consistency. Such genotypes are imperative for wheat cultivation, providing reliability and mitigating risks associated with environmental variability. Moreover, the study highlights genotypes like WAPD 1505, HI 1634, and DBW 71, which exhibited stability in unfavorable conditions. This finding is vital, considering the research by Soleman Mohamed Al-Otayk (2010) [6] and Jaberson *et al*. (2017) [12], which also focused on varietal responses to distinct environmental stresses. The variety in genotype responses underscores the potential for developing specialized wheat varieties suited for specific climatic or environmental scenarios, an approach that could be instrumental in addressing the challenges posed by climate change.The substantial linear aspect of the genotype-environment interaction mirrors the findings of Arain *et al.* (2011) [7], Mahmoud *et al.* (2011) [8], and Birla *et al. (*2012) [10], emphasizing the predictable pattern of how genotypes interact with their environments. This understanding is priceless for breeders, as it suggests that while the genetic composition is crucial, the adaptability of genotypes to various environmental conditions also plays a significant role in determining overall performance.

Table 1.Stability Analysis of variance for grain yield and its attributing traits in wheat

Source of Variation	DF	DH	DM	PH (cm)	NTPP	SL (cm)	SW (g)	PL (cm)	NSPS	NGPS	BYPP (g)	HI (%)	TGW	GYPP
Genotypes	29	6.31**	19.28**	61.70**	1.86**	0.416**	0.12**	7.46**	5.51**	41.26**	57.15**	39.36**	63.60**	8.97**
Env+Var X Env	60	19.44**	7.98**	123.56**	0.69**	1.196**	0.44**	2.25**	0.73**	30.12**	112.22**	68.16**	6.64**	39.02**

Env (Linear)	1	271.93**	111.50**	1497.54 **	9.44**	15.317**	4.62**	32.80**	11.01**	211.71**	712.29**	626.26**	95.01**	386.67**
Env X Var(Lin)	29	1.33**	0.79**	14.42**	0.04**	0.154**	0.08**	0.07**	0.007**	10.11**	44.15**	15.66**	0.29**	7.30**
Pooled Deviation	30	28.53**	11.48**	183.26**	1.03**	1.732**	0.65**	3.35**	1.104**	43.41**	158.02**	100.30**	9.83**	58.10**
Pooled Error	87	9.17**	13.09**	59.74**	0.95**	0.865**	0.31**	8.26**	2.037**	37.44**	82.78**	95.15**	25.97**	14.01**
Total	89													

*Note- * & ** indicate levels of significant at 5% and 1 %, respectively.*
DH- days to fifty percent heading, DM- days to maturity PH- plant height, NTPP- number of tillers per plant, SL- spike length,SW- spike weight, PL- peduncle length, NSPS- number of spikelets per spike, NGPS- number of grain per spike, 1000 GW-thousand grain weight, BYPP- biological yield per plant, HI- harvest index, GYPP- grain yield per plant.

Table2. Stability parameters (ER 1966) for grain yield per plant

	Grain yield per plant		
Genotypes	**Mean**	**βi**	**S²Di**
GW 432	15.335	-0.349	-6.758
PBW 760	14.898	1.782	86.862
HD 3317	16.025	2.695	166.314
IC 296769	13.158	0.693	16.366
MP 3336	14.124	1.826	90.43
HS 661	14.144	1.183	40.212
HI 1624	16.748	1.214	41.991
PBW 820	15.05	0.946	31.552
HD2967	15.11	-0.36	-6.802
GW 328	18.269	-0.32	-6.626
DBW 107	17.185	1.829	90.735
MP 4010	18.752	0.949	120.885
GW 190	16.275	0.823	6.051
K 1317	14.933	0.966	32.615
HI 1634	19.023	0.944	1.79
USA NG 326	15.335	0.294	-6.308
HI1628	14.898	1.446	100.83
WAPD 1505	16.025	1.828	216.875
HD 3237	13.158	0.819	13.91
WGW 2014 596	14.124	1.468	105.605
CG 1029	14.144	1.066	43.601
GW 3211	16.748	1.082	45.902
JW 17	15.05	1.025	29.543
PBW 797	15.11	0.289	-6.208
GW 499	18.269	0.309	-6.534
DBW 110	17.185	1.47	106.015
DBW 71	18.752	1.603	152.959
GW 322	16.275	0.672	2.3
JW 3382	14.933	1.035	30.836
Lok 1	19.023	5.031	-1.975
Population mean	15.93527		

*Note- * & ** Significant At 5% And 1% Levels, Respectively*

5. CONCLUSION

The findings of this investigation lead to the inference that within the group of wheat types assessed, GW 322 and MP 3336 stand out as the most suitable and consistent for achieving excellent grain yield per plant. Furthermore, genotypes like DBW 107, HD 3317, along with GW 322 and MP 3336, exhibit consistency in stability across various yield-related characteristics. This stable genotypescan be crucial for effectively incorporating them into different cultivation schemes, ensuring strong yield performance in different seasons and regions. Moreover, these identified genotypes are valuable resources in the efforts to create new wheat varieties through hybridization. Their consistent yield attributes under different environmental conditions can make a significant contribution to progress in wheat breeding, ultimately enhancing yield resilience and stability.

ACKNOWLEDGEMENTS

The authors express gratitude to everyone who contributed to the current investigation, whether through direct or indirect involvement. They also extend their thanks to the Department of Plant Breeding & Genetics at the College of Agriculture, JNKVV, Jabalpur for granting essential facilities throughout the research.

COMPETING INTERESTS

Authors have declared that no competing of interest was reported.

Authors' contributions

This work is carried out in collaboration among all the authors. All authors read and approved final manuscript.

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