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Research Article

Genetic variability and character association studies in bread wheat (*Triticum aestivum* L.) under two different water regimes

Divya Chaudhary*, Swati, Anil Kumar, Basu Sudhakar Reddy and Rohit

Department of Genetics and Plant Breeding, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttrakhand-263145, India
***E-Mail:** divyagpb1@gmail.com

Abstract
The present study was undertaken to estimate the GCV, PCV, heritability, genetic advance, and correlation for yield and its attributes in a set of forty-nine bread wheat genotypes, assessed under irrigated and rainfed conditions. Relatively high GCV, PCV, heritability, and genetic advance were found for TPP, GYP, and BYP in both conditions. It implying that crop improvement can be achieved by selecting these traits and such characters could be transmitted through hybridization to the progeny. In the correlation study, the highest significant positive correlation was observed between GPS and GWS in both environments. The results demonstrated that TPP and BYP are important components for improving grain yield in both irrigated and rainfed conditions.

Keywords: Wheat, Heritability, Genetic advance and Correlation

INTRODUCTION

Wheat is the world's most widely grown food crop, and it ranks second after rice in Indian agriculture. It belongs to the genus "*Triticum*" and is a cereal grass that undergoes self-pollination, classified within the Poaceae family. Because of its wide cultivation, exceptional productivity and substantial contribution to the global grain trade, it has earned the nickname "King of Cereals." This grain is abundant in nutrients and plays a vital role in ensuring food security, reducing poverty and supporting livelihoods. In order to sustain the projected global population of 9.7 billion by 2050 (Gimenez *et al.,* 2021), wheat yields need to improve by an annual growth rate of 2.4% over the next three decades. This objective would be feasible under ideal growing conditions, but it is unlikely to be achieved in the face of climate change, which impacts not just average yield but also yield stability. In semi-arid regions worldwide, drought stress stands as a primary factor that significantly restricts wheat yield. It affects the yield and different morpho-physiological attributes of plants (Chaudhary *et al.,* 2023). To provide sustenance for a continuously expanding population with diminishing water resources, there is a requirement for crop varieties that possess excellent adaptation to arid conditions (Foley *et al.,* 2011). The presence of drought exerts an adverse influence on the growth, development, production of dry matter, and the potential yield of crops (Ayed *et al.,* 2021).

Cultivated varieties do possess genetic potential for achieving high yields, but the presence of both biotic and abiotic stress interactions reducing yield stability. It is crucial to comprehend the scope and characteristics of phenotypic and genotypic diversity in crop species to establish a successful breeding program aimed at producing enhanced cultivars. As stated by Vavilov (1951), greater diversity increases the chances of obtaining favorable genotypes, which has ultimately proven to be fundamental in the advancement of agricultural plant development through selective breeding. The ability to improve crop yields is primarily influenced by the type and degree of variability present. Hence, a successful breeding program should encompass genetic variability among the genotypes. Accordingly, it is essential to explore estimates of genotype variability. The evaluation of genetic potential, diversity, and stability performance relies on statistical parameters like heritability, Genotypic Coefficient of Variation (GCV), Phenotypic Coefficient of Variation (PCV), and genetic advance (Ali *et al.,* 2008). Grain yield is a complex trait that is significantly impacted by diverse environmental factors. Therefore, it becomes crucial to differentiate the overall variation into heritable and non-heritable components using genetic parameters such as GCV, PCV, heritability, and genetic gain (Kahrizi *et al.*, 2010). The phenotypic variance indicates the extent of variation resulting from both genetic components and environmental factors. Heritability represents the genetic relationship between parents and offspring. It is an established fact that greater variability among genotypes increases the potential for further enhancements in the crop.

Both the genotype and the environment significantly influence the grain yield and yield components of wheat. Consequently, breeders thoroughly examine the associations between yield and its various components when developing new cultivars through breeding methods. In order to enhance the yield, it is essential for a successful breeding program to investigate the direct and indirect impacts of yield components. This enables a more effective approach to address the issue of yield increase by considering the effectiveness of the yield components and selecting closely related traits (Mecha *et al.,* 2017). The objective of the present study was to identify the best traits among wheat genotypes, aiming to strengthen ongoing breeding programs. This was achieved through assessing genetic variability, heritability, genetic advance, and correlation for different traits under irrigated and rainfed environments.

MATERIALS AND METHODS

The study involved evaluation of 11 lines (including drought-tolerant wheat varieties, namely C306, VL3001, UP2572, WH1080, WH1142, and PBW644), three testers, 33 hybrids generated by crossing the above in L X T fashion and two standard checks (HD2967 and PBW660) (**Table 1**). The genotypes were raised in experimental plots consisting of two rows, each measuring one meter in length, with a row-to-row spacing of 20 cm and a plant-to-plant spacing of 10 cm within each row in randomized block design with three replications. The experiment was laid out at the N.E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology in Pantnagar, India, under both irrigated (E1) and rainfed (E2) conditions during the *Rabi* season of 2018-2019. The meteorological data for each week throughout the crop season is depicted in **Fig. 1**. Pantnagar is situated in the "*Tarai*" region, which is located in the subtropical zone and lies at the foothills of the Shivalik Himalayan range at a latitude of 29.50^{0}N and a longitude of 79.30^{0}E with elevation of 243.84 meters above MSL. In this

Table 1. Experimental material

S. No.	Pedigree/ Lines
Lines	
1	BECARD/KACHU
2	BOW/VEE/5/ND/VG9144//KAL/BBB/YACO/4/CHIL/6/CASKOR/3/…
3	92.001E7.32.5/SLVS/5/NS-732/HER/3/PRL/SARA//TSI/VEE#5/…
4	FRANCOLIN#1/BAJ#1
5	KACHU*2//WHEAR/SOKOLL
6	PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/4/BERKUT//…
7	UP2572
8	VL3001
9	NW5054
10	PBW644
11	C306
Testers	
1	WH1080
2	WH1142
3	HD3086
Checks	
1	HD2967
2	PBW660

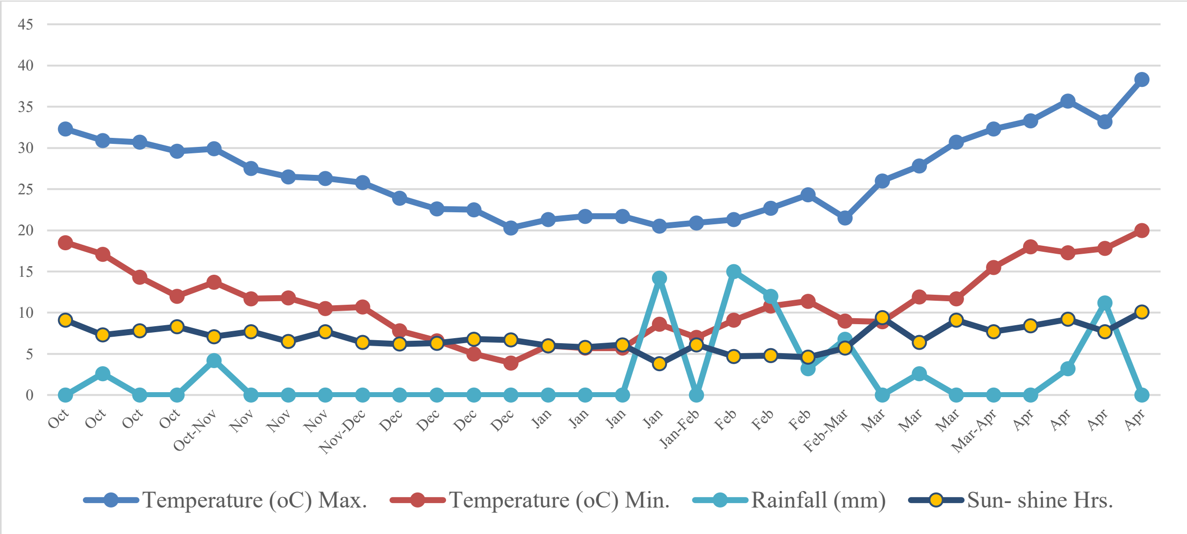

Fig. 1. Weekly metrological data from October (2018) to April (2019)

research, only a single irrigation was applied during the tillering stage, after which no further irrigation was utilized to induce moisture stress. Conversely, under irrigated condition, the wheat genotypes received four irrigations at key growth stages: crown root initiation, tillering, flowering, and dough formation to facilitate their optimal development. The total water demand for the entire wheat crop production period falls within the range of 450-650mm (Tadesse *et al*., 2017). During the entirety of the *rabi* season in this experiment, the total recorded rainfall was 75.8mm (**Fig. 1**). In the rainfed environment (E2), a notable absence of rainfall from the tillering to the booting stage, spanning from November to January. Based on the meteorological data presented in **Fig. 1**, it is evident that the stress criteria were met for the E2 environment. Data was recorded on days to 75% heading (DH), tillers per plant (TPP), plant height (PH) (cm), spikelets per spike (SPP), grains per spike (GPS), 1000 grain weight (TGW) (g), grain weight per spike (GWS) (g), grain yield per plant (GYP) (g) and biological yield per plant (BYP) (g). The collected data were analysed for different genetic variability parameters like GCV, PCV, broad sense heritability (h^2_{bs}) %, and genetic advance as a percentage of mean (GAM) (%) using “variability” package (Popat *et al.,* 2020) in R-studio. Further categorization of these parameters was conducted based on Sivasubramanian and Menon (1973); Robinson *et al.* (1949) and Johnson *et al.* (1955). The estimates of correlation among nine traits under study for both environments were calculated using package “metan” (Olivoto and Lúcio, 2020).

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among the genotypes for all the quantitative traits in both conditions, as indicated in **Table 2**. Hence, Genetic variability among genotypes facilitated the selection of suitable ones for both E1 and E2 environments. **Table 3** presents the GCV, PCV, h^2_{bs}, and GAM values for all the quantitative traits in the respective environments. PCV was slightly higher than GCV for all the traits in both conditions revealing that the expression of character was affected by environments. In this study all the parameters showed a minor difference between the GCV and PCV values indicating minimum environmental influences and consequently greater role of genetic factors on the expression of traits. Heidari *et al.* (2020) also reported similar findings by evaluating wheat genotypes in rainfed and supplementary irrigation conditions. The GCV and PCV were higher for all the traits in a rainfed environment compared to irrigated conditions, except for PH and TGW, and PCV was higher in irrigated conditions for GWS, showing that the selection of best genotypes for a majority of traits is highly effective through breeding programs in rainfed environments. The highest PCV and GCV were observed for BYP (29.33 and 29.06, respectively) followed by TPP (22.87 and 21.99, respectively) in the E1 environment. Whereas, in E2 highest PCV and GCV were identified for TPP (38.45 and 36.66, respectively) followed by GYP (35.51 and 33.43, respectively). Thus, high PCV and GCV for these traits indicate better opportunities for improvement in these traits through selection. Based on the characterization of genetic parameters proposed by Sivasubramanian and Menon (1973) the high PCV and GCV were observed for TPP, GYP, and BYP in both E1 and E2 environments. The medium values for these estimates were recorded for GPS and GWS in both environments. Whereas, genotypes showed low PCV and GCV for the traits DH, PH, SPP, and TGW, indicating less genetic and phenotypic variability among the genotypes for these traits. The results are parity with the findings of Morteza *et al.* (2018), Heidari *et al.* (2020) and Sadgar *et al*. (2021).

Table 2. ANOVA for quantitative traits

S.No.	Source of variation	d.f.	ENV	DH	TPP	PH	SPP	GPS	TGW	GWS	GYP	BYP
1	Replication	2	E1	2.84	0.74	7.15	0.35	5.99	0.26	0.01	1.76	1.90
			E2	8.14	0.59	6.72	0.65	7.48	4.83	0.12	3.43	11.73
2	Genotype	48	E1	19.83**	42.41**	247.97**	7.68**	223.01**	37.34**	0.50**	80.06**	1496.34**
			E2	46.05**	21.75**	110.88**	8.78**	237.18**	34.50**	0.72**	131.74**	590.66**
3	Error	96	E1	1.50	1.12	2.49	0.48	2.18	1.70	0.13	2.45	9.16
			E2	2.67	0.70	2.23	0.63	2.49	2.56	0.08	3.40	7.23

E1= Irrigated, E2= Rainfed, ENV= Environments, d.f.= degree of freedom, **= Significance at 1% probability levels

Table 3. Genetic parameters for quantitative traits under irrigated and rainfed conditions

Characters	Irrigated				Rainfed			
	GCV	PCV	h^2_{bs}	GAM	GCV	PCV	h^2_{bs}	GAM
DH	2.81	3.14	80.25	5.19	4.04	4.39	84.39	7.64
TPP	21.99	22.87	92.45	43.56	36.66	38.45	90.90	72.00
PH	9.01	9.14	97.04	18.28	6.56	6.76	94.19	13.12
SPP	7.42	8.13	83.40	13.96	8.41	9.32	81.29	15.61
GPS	13.04	13.24	97.13	26.48	14.85	15.08	96.92	30.11
TGW	8.11	8.67	87.47	15.62	6.99	7.79	80.58	12.93
GWS	13.09	18.64	49.28	18.93	17.14	18.06	90.02	33.49
GYP	21.33	22.32	91.34	42.00	33.43	35.51	88.63	64.84
BYP	29.06	29.33	98.18	59.33	32.89	33.41	96.90	66.70

The estimation of heritability plays a crucial role in assisting breeders in determining the heritable portion of variation attributed to genotypes. When a character demonstrates high heritability (>60%), selection becomes relatively easy as there is a close correspondence between genotypic and phenotypic variations, with the environment playing a smaller role in determining the phenotype. However, in cases where a character exhibits low heritability (<30%), selection may be challenging or impractical due to the complex influence of the environment on the genotypic effect of that particular character. The genotypes showed high h^2_{bs} (>60%) for all the traits in both environments, except for GWS (49.28%) in irrigated conditions. It indicates that high component of the heritable portion of variation for most of the traits that breeders can exploit in the selection of superior genotypes based on phenotypical performance. The high h^2_{bs} was observed in the E2 environment than E1 for all the traits, except for DH and GWS. This suggests that under irrigated conditions, genotype performance is more influenced by the environment when compared to rainfed conditions. Morteza *et al.* (2018), Sadgar *et al.* (2021), Chauhan *et al.* (2022), and Sharma *et al.* (2022) also observed high heritability for yield and its component traits in wheat.

Relying solely on heritability estimates does not provide comprehensive information regarding the extent of genetic progress. Johnson *et al.* (1955) illustrated that combining h^2_{bs} and GAM provides more reliable insights for determining the best genotype. Consequently, the calculation of GAM was performed to assess the relative advantages of different traits, thereby facilitating their utilization in the selection process. When comparing different traits across environments, it was found that the high estimate of GAM was recorded for TPP (43.56 in E1 and 72.00 in E2), GPS (26.48 in E1 and 30.11 in E2), GYP (42.00 in E1 and 64.84 in E2), and BYP (59.33 in E1 and 66.70 in E2) in both environments and also for GWS (33.49) under rainfed condition. Whereas, moderate GAM was recorded for PH (18.28 in E1 and 13.12 in E2), SPP (13.96 in E1 and 15.61 in E2), and TGW (15.62 in E1 and 12.93 in E2) in both environments and for GWS (18.93) only under irrigated condition. Low GAM was observed for DH (5.19 in E1 and 7.64 in E2) in both environments. The high h^2_{bs} and high GAM were observed for traits such as TPP, GPS, GYP, and BYP in both environments and also for GWS under rainfed conditions. Traits that demonstrate both high h^2_{bs} and high GAM estimates are considered the most advantageous for selection purposes. This implies that the trait is predominantly influenced by additive gene action, indicating that selecting these particular traits can lead to notable enhancements in crop improvement (Ogunniyan and Olakojo, 2014). Similarly, high h^2_{bs} with high GAM was also reported by Sadgar *et al.* (2021) for grain yield, 1000 grain weight, and productive tillers per meter; Emmadishetty and Gurjar (2022) reported for GYP and BYP. Whereas, high h^2_{bs} with low GAM was recorded for DH in both E1 and E2 environments. This may be because of the predominance of non-additive gene action in the expression of these traits. The high heritability observed in these traits can be attributed to the favourable impact of the environment rather than the genotypic component, suggests that selecting them may not be rewarding in terms of achieving significant improvements. Sadgar *et al.* (2021) reported high h^2_{bs} with moderate GAM for days to 50% heading; Sharma *et al.* (2022) observed high h^2_{bs} and low GAM for days to 50% heading in the analysis of wheat genotypes. Relatively high GCV, PCV, heritability and genetic advance obtained for TPP, GYP, and BYP under both irrigated and rainfed condition. Such characters could be transmitted through hybridization to the progeny and phenotypic selection would be effective.

In this study highest significant positive correlation was observed between GPS and GWS in both environments and hence breeding for increase in GPS in both environments would be relevant to increase in GWS (**Fig. 2 and Fig. 3**). Other yield attributes, such as TGW showed significant positive correlation with GWS in both environments and with PH only in irrigated condition. SPP showed significant positive correlation with GPS in both environments and also with DH in rainfed condition. GWS showed significant positive correlation with GPS and SPP in rainfed condition. Similarly, Khairnar and Bagwan, (2018) also observed significant positive correlation between GPS and GWS. Grain yield is primarily breeding objective which showed significant positive correlation with TPP and BYP in both conditions. The attributes GPS, GWS, SPP, PH and DH also showed positive correlation with GYP in both environments. So, these traits can help in improve indirect selection for grain yield. Similar results also observed by Mecha *et al.* (2017), Khairnar and Bagwan, (2018) and Shimelis *et al.* (2019). The BYP showed significant positive relationship with TPP and PH in both environments implying the strong association among the traits that is not influenced by the environment. The simultaneous selection of these traits will increase the biomass of plant. The significant negative association was observed for DH with PH and TGW only in irrigated condition. Similarly, Ullah *et al.* (2018) also observed significant negative correlation between DH and TGW in advanced lines of wheat.

In conclusion, high genetic variability was found among the studied bread wheat genotypes for TPP, GYP and BYP in both irrigated and rainfed conditions. In both environments, TPP, GPS, GYP and BYP showed high heritability and high genetic advance. Therefore, selection can be done based on these traits in both environments. Results showed that TPP and BYP are important components for increasing grain yield in both irrigated

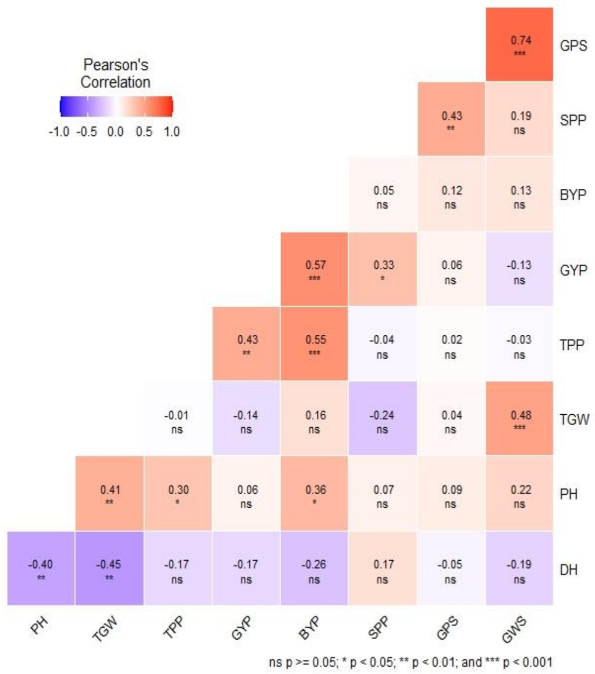

Fig. 2. Simple correlation coefficients for quantitative traits under irrigated condition

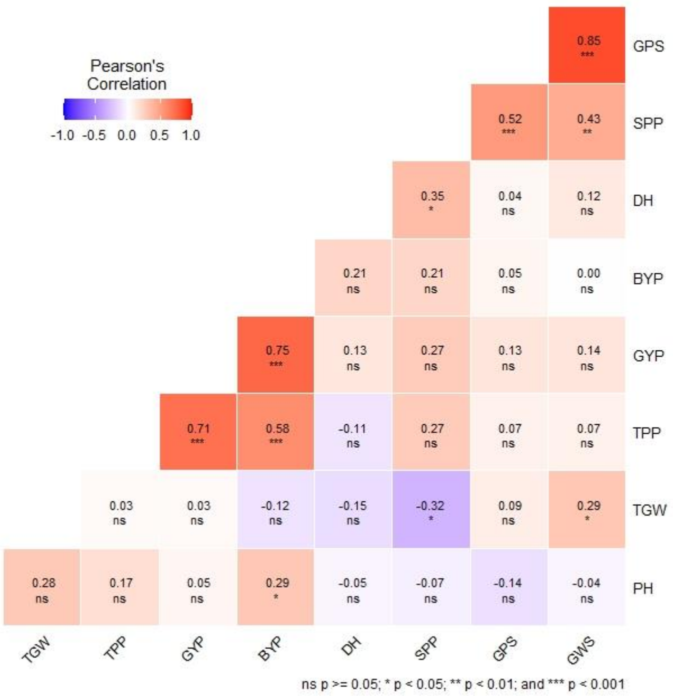

Fig. 3. Simple correlation coefficients for quantitative traits under rainfed condition

and rainfed condition. Hence, these traits can be selected in both environments to enhance grain yield.

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