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Genetic Variability and Correlation Coefficient Analysis in Wheat Genotypes for Grain Yield and Its Contributing Traits under Drought and Irrigated Condition

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ABSTRACT
Direct phenotypic selection in wheat improvement program requires preliminary knowledge of traits association degrees. In this study, a field experiment was conducted on the wheat crop in two different conditions (irrigated and drought), in order to determine the degree and direction of the association between grain yield and its attributing characters. The experimental findings indicated that correlation coefficients showed a highly significant and positive association between grain yield and harvest index followed by above ground biomass. However, other traits have a significant indirect impact on grain yield through the harvest index and above ground biomass. According to this, choosing genotypes with higher yields would be more effective if selection were based on these traits. The minimum yield reduction irrigated conditions was observed for the genotypes WH1127, WH1164, WH1105, WH1080, IC498438, EC609554, and EC609575. In the light of the fact that these genotypes have the higher yield potential under moisture stress condition and could be utilized as donors in bread wheat improvement program for drought tolerance.

Keywords: Correlation coefficient, GCV, grain yield, PCV and wheat

Introduction

The bread wheat (*Triticum aestivum* L., 2n=6x=42, AABBDD), the third-largest cereal food crop in the world, is ranked first in terms of cultivated area and second in terms of production among cereal crops worldwide (FAO, 2020). With a projected total production of 765.53 million tons in the 2018/2019 cropping season, wheat was grown on approximately 218.22 million hectares across the world (USDA, 2022). To feed the anticipated 9.1 billion people by 2050, production of cereals should increase by 1 billion tons year, according to estimates (FAO 2015). In order to satisfy the rising demands for food supply, the current situation requires an increase in crop productivity (Iqbal et al., 2017). Water scarcity is a severe drawback that limits the area under cultivation and agricultural output in arid and semi-arid regions all over the world.

Abiotic stresses have a significant impact on wheat grains' protein content, which alters the quality of baked goods (Zorb et al., 2018). According to Rakszegi et al*.,* (2019), wheat grain's protein, gliadins, glutenin, and fiber composition are all significantly impacted by drought stress. Drought stress significantly alters the crop's physiological, morphological, biochemical and molecular mechanisms which hinders plant growth (Sultan et al*.*, 2012). Drought can happen at any stage of growth and development (Belay et al., 2021). High-yielding cultivars with superior water usage efficiency can be essential in environments with extreme drought, but progress has been delayed as a result of the unpredictable nature of drought and the complex genetic regulation of plant responses.

Wheat grain yield is a complex polygenic trait that is impacted by a wide range of variables and can be improved based on yield components via indirect selection. In such a way, that increase in one component may affect the other components positively or negatively. Understanding the genetic makeup of yield component parts is crucial for this reason. The tillers no., grain weight (1000), length of spike and number of spikelet per spike, etc., are associated that could be utilized for estimating the grain yield (Li et al., 2020). Drought not only influences the morphological characteristics of wheat crop, but also wheat physiology. Several physiological characters have higher heritability and could be helpful in enhancing the drought tolerance of wheat crop. Evidently, stay-green phenotypes can increase their performance under moisture stress conditions with delayed leaf senescence (Lopes and Reynolds, 2012).

Evaluation of morpho-physiological changes under drought may aid in genetic improvements of wheat genotypes since bread wheat differentially respond at vegetative growth phases under water deficit situation (Chowdhury et al., 2021). Understanding the morpho-physiological traits linked to grain yields under moisture stress is crucial for improving bread wheat (Zhang et al., 2016). Wheat breeders must focus on improving drought resistance, which is genetically determined and had a significant impact in the stability of the crop. Improvement in grain yield and stress tolerance has primarily been attained through empirically or through grain yield selection.

Subhani et al., (2000) observed significant and positive association among the morphometric traits such as biomass, harvest index, tillers no. (per plant), length of peduncle, length of spike, 1000-grain weight, and number of grains per spike, grain yield per plant but significant and negative correlation of days to heading with grain yield per plant was also found. According to Khames et al., (2016) and Jan et al., (2017), grain yield had a positive phenotypic association with 1000-grain weight and number of tillers per plant. In a study, Rehman et al., (2015) examined the behavior of 100 genotypes of wheat under drought stress conditions. The findings showed that there was a positive and significant correlation between spike length, peduncle length, spikelet per spike, and grain yield. The current study's objective was to identify important drought adaption characters and variations in these traits in bread wheat grown both under irrigation and moisture stress conditions.

Material And Methods

Experimental Materials:

The experimental material included 40 wheat germplasm accessions whose descriptions are shown in Table 1.

Layout of Field Experiment

At the Field Research Area, CCS HAU, Hisar, seeds of all forty genotypes were sown in a randomized block design (RBD) with three replications during *rabi* 2018–19. The study was carried over the course of a year, with each plot consisting of paired rows of 2.5 m length, with row to row distance of 20 cm and plant to plant 10 cm in every replication. At 40-45 days after sowing, one irrigation was given for drought condition; however, under irrigated condition, six irrigations were given.

Observations Recorded and Statistical analysis

Except for the days to heading and days to maturity, observations were recorded on five randomly chosen plants from each genotype in each replication. The data were recorded for days to heading, plant height (cm), days to maturity, peduncle length (cm), number of effective tillers per plant, spike length (cm), number of grains per spike, harvest index (%), above ground biomass per plant (g), canopy temperature, 1000-grain weight (g), grain yield per plant (g), NDVI and SPAD. Instrument Green Seeker TM, a handheld optical sensor, was used to record NDVI carried out at Z45 stage according to Zadoks Growth Scale. Using a SPAD-502 chlorophyll meter, the mean chlorophyll of the flag leaves of five tagged plants was calculated for SPAD at Z49 stage. With a handheld infrared thermometer, CT was measured between 12:00 and 14:00 at the Z47 stage in clear and sunny weather.

Result and Discussion

According to the findings of the current study, under both conditions, grain yield per plant had the highest GCV, followed by above ground biomass per plant, harvest index, no. of effective tillers per plant, 1000-grain weight, no. of grains per spike, plant height, and so on. Compared to genotypic coefficient of variance, phenotypic coefficient of variation was higher for each of the characters under study. Usually, phenotypic variance exceeds its corresponding genotypic variance, but minimal variance must be attained to increase the heritability. Similar findings were made by Bhushan, et al., (2013) and Abinasa et al., (2011). Among both the conditions, PCV was higher in irrigated and it was found to be highest for the grain yield per plant followed by above ground biomass per plant, harvest index, effective tillers per plant, 1000-grain weight, grains per spike, and so on.

The estimates of broad sense heritability ranged from 70.20% - 96.75% under irrigated condition and 72.82%- 98.13% under drought condition. Characters which exhibited high heritability included plant height, days to heading, above ground biomass (per plant), grains per spike, length of peduncle, grain yield per plant, and effective tillers per plant. Under moisture stressed condition, estimates of high heritability were also reported by Itam et al., 2021 for plant height (81%), days to heading (84%), and 1000-grain weight (91%); Olbana et al., 2021 for biomass yield, days to heading, plant height, days to maturity and spikelets per spike; Shamuyarira, et al., 2019 for days to heading (78.8%) and Semahegn et al., 2020 for days to heading (91.5%), days to maturity (80.5%), spike length (79.2%), spikelets per spike (78.4%), and plant height (74.1%).

Another crucial selection factor that helps breeders in a selection program is genetic advance. The highest genetic advance was found for plant height, which was followed by above ground biomass per plant, grains per spike, days to heading, harvest index, 1000-grain weight, peduncle length, grain yield per plant, days to maturity, effective tillers per plant, and spike length. In the addition, grain yield per plant had the highest genetic advance as percentage mean, followed by above ground biomass per plant. Similar findings were reported by Birhanu et al., (2017). Alemu et al., (2019) reported lowest value of genetic advance as percentage of mean for days to maturity and also in this study. High genetic advance as percentage of mean was observed by Singh et al., (2014) for grain yield and number of tillers per plant. Prior to making a selection, estimates of heritability are helpful for figuring out the characters that must be taken into account, but making a decision solely based on this aspect might restrict advancement, because it is vulnerable to environmental changes. Subsequently under drought stress condition, for grain yield per plant and above ground biomass high heritability values along with high genetic advance as percentage of mean were observed. Therefore, for the genetic enhancement under drought condition, immediate selection can be performed using such traits.

Aslani et al., (2012) and Hassan et al., (2016) also noted high variability for component traits and grain yield per plant, and Pokhrael et al., (2012), Singh et al., (2018), and Adnan et al., (2013) observed high variability for biomass yield. (Table 3, 4, 5 and 6) According to mean performance of the quantitative traits, genotypes WH1127, WH1164, WH1105, WH1080, IC498438, EC609554, and EC609575, displayed the least variation between irrigated and drought conditions. Meanwhile, genotypes such as EC178071-210, and IC529429 were found to exhibit a little high grain yield per plant and harvest index in drought condition over irrigated while genotype IC529189 displayed better expression of NDVI, C.T, and SPAD.

The Pearson's correlation coefficients between traits under stressed and non-stressed conditions are shown in Table 7, 8, 9 and 10. From the Correlation research, genetic upgradation in one character could be accomplished by choosing the other pair. Correlation analysis determines the reciprocal association between several plant characteristics and determines the individual characteristics on which selection can be centered for the enhancement of genetic yield. It is possible to predict that the least divergent genotypes will be the most stable for the given character.

According to this study, under irrigated conditions, grain yield per plant was positively associated with harvest index, above ground biomass per plant, grains per spike, spike length and days to heading, whereas under drought conditions, it was positively associated with above ground biomass followed by harvest index, effective tillers per plant, plant height, and 1000-grain weight. Similar outcomes were attained by Baye et al., (2020) and Javed et al., (2022). Effective tillers per plant associated positively with above ground biomass per plant under both conditions, but negatively with harvest index under the irrigated condition and positively but insignificantly under the drought condition. According to Munir et al., (2007), biological yield had a positive and significant relationship with grain yield and tillers per plant but a negative relationship with days to heading and harvest index. The simple correlation analysis by Ayer et al., (2017) in advanced wheat genotypes revealed a significant positive association between grain yield and 1000-grain weight, plant height, biomass yield, and harvest index. Under both conditions, plant height had a positive association with peduncle length, effective tillers per plant, 1000-grain weight, and biological yield per plant, however, a negative association with harvest index under the irrigated condition. Reza et al., (2014) provided evidence of a significant and positive association between plant height and grain yield in drought-like conditions. According to Gelalcha and Hanchinal (2013), under both conditions, there existed a positive and significant association among number of grains per spike and grain yield per plant. Days to heading showed a negative association with biological yield per plant under both the conditions.

Both the number of grains per spike and the number of spikelets per spike were found to be positively correlated with grain yield. H. Fouad (2018) reported findings that were comparable. Under both conditions, peduncle length had a positive correlation with 1000-grain weight and above ground biomass per plant but associated negatively with harvest index under irrigated condition. Meanwhile, days to maturity showed a positive association with plant height and peduncle length in both conditions, as well as with grains per spike in case of drought. Days to maturity were found to be positively associated with above ground biomass per plant under both circumstances, though not significantly. According to Talebi (2011) and Kumari et al., (2012), chlorophyll content is associated positively with grain yield and a significant and positive association was found between SPAD and grain yield under both condition while under drought condition C.T showed a negative association with the grain yield. According to Kashif and Khaliq (2004), under drought conditions, a significant but adverse phenotypic association between canopy temperature and the number of grains per spike was found. Chlorophyll content is a crucial characteristic that can be used as a stand-in for drought resistance and increased grain yield.

The relationships between these characteristics revealed that they are governed several common genes, can be used as a selection factor in breeding projects. The other correlated traits would also get better as a result of the positive selections for one trait. According to the results of this study, genotypic correlations in drought tolerance may produce predictable correlated responses that can be used to choose wheat that is drought-tolerant in breeding programs.

Conclusions

This study showed that the traits in wheat germplasm have a wide range of variability. Under irrigated condition, PCV was higher than drought condition. Plant height exhibits high heritability and high genetic advance, suggesting that selection may be used to further improve this trait. Under both the conditions, above ground biomass per plant and harvest index showed a highly significant and positive association with the grain yield per plant. Characters namely, no. of effective tillers per plant, grains number per spike, grain weight (1000) and spike length etc. exhibited significant indirect effects on the grain yield per plant via harvest index and above ground biomass per plant in path coefficient analysis. Crop varieties with higher levels of chlorophyll and slower chlorophyll deterioration may be more drought-tolerant. Physiological characters like SPAD showed highly significant and positive association with the grain yield.

For most of the studied characters, it seemed that genotypes WH1127, WH1164, WH1105, WH1080, IC498438, EC609554, and EC609575 showed the least yield reduction under both irrigated and dry environments. Additionally, under drought conditions, genotypes IC498438, EC609575, HD2967, EC178071-210 and IC529429 demonstrated a slightly higher grain yield per plant and harvest index. It is possible to say that these genotypes have a higher yield potential and direct selection of these genotypes will be beneficial for future breeding programs.

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Table 1. An inventory of the wheat accessions used in the research program.

Sr. No	Genotypes	Sr. No	Genotypes	Sr. No	Genotypes	Sr. No	Genotypes
1	IC529429	11	IC539103	21	EC609575	31	WH1142
2	DT5	12	DT25	22	EC609594	32	WH147
3	IC558801	13	DT45	23	EC609563	33	WH1126
4	IC529909	14	IC539162	24	EC609550	34	WH1127
5	IC539456	15	IC145729	25	EC178071-631	35	WH1164
6	IC539543	16	IC529210	26	EC178071-210	36	WH1235
7	IC529189	17	IC296762	27	EC177816	37	WH1105
8	IC539518	18	IC128157	28	EC609589	38	HD 2967
9	IC539167	19	IC543376	29	C306	39	HD3086
10	IC498438	20	EC609554	30	WH1080	40	DPW621-50

Table 2. Statistical approaches adopted.

Sr. No	Statistical Analysis	Reference	Year
1	ANOVA	Ronald Fisher	1918
2	Correlation Coefficient	Al-Jibouri et al.,	1958
3	Variance Coefficients (GCV and PCV)	Burton	1953
4	Heritability (in broad sense)	Hanson	1956
5	Genetic advance	Johnson et al.,	1955
6	Genetic advance as percent of mean	Johnson et al.,	1955

Table 3. Mean performance, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, genetic advance and genetic advance (GA) as per cent of mean under irrigated condition.

Characters	Mean	Range	GCV (%)	PCV (%)	Heritability (h^2_{bs}) (%)	Genetic Advance	Genetic Advance as % Mean
Days to heading	103.13	92-119	5.59	5.74	94.92	11.57	11.22
Days to maturity	149.24	146-153	1.07	1.25	73.25	2.81	1.88
Plant height	106.18	85-138	12.21	12.41	96.75	26.28	24.75
Spike length	11.49	10-14	10.03	11.67	73.85	2.04	17.76
Peduncle length	37.67	31-49	10.65	11.69	83.02	7.53	20.00
Effective tillers per plant	9.75	6-13	14.62	16.78	75.93	2.54	26.25
Grains per spike	58.27	44-76	12.58	13.60	85.51	13.96	23.96
1000-grain weight	38.76	24-49	12.72	15.41	70.65	8.54	22.03
Grain yield per plant	11.38	7-19	22.65	25.68	77.79	4.68	41.16
Biological yield per plant	34.92	20-52	21.03	21.79	93.12	14.60	41.82
Harvest index	33.47	25-41	19.51	23.28	70.20	11.27	33.68

Table 4. Mean performance, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, genetic advance and genetic advance (GA) as per cent of mean under drought condition.

Characters	Mean	Range	GCV (%)	PCV (%)	Heritability (h^2_{bs}) (%)	Genetic Advance	Genetic Advance as % Mean
Days to heading	101.50	86-119	5.77	5.92	93.62	11.69	11.51
Days to maturity	143.49	141-147	0.85	0.98	74.84	2.18	1.51
Plant height	99.75	77-139	14.87	15.01	98.13	30.28	30.36
Spike length	11.26	9-14	10.20	11.51	78.52	2.09	18.63
Peduncle length	37.00	28-52	14.03	15.82	78.66	9.50	25.64
Effective tillers per plant	9.47	6-15	17.81	19.53	83.16	3.14	33.47
Grains per spike	42.42	33-58	12.75	14.65	75.68	9.69	22.85
1000-grain weight	37.87	24-48	15.35	17.99	72.82	10.21	26.98
Grain yield per plant	10.80	7-14	18.67	21.52	75.30	3.59	33.38
Biological yield per plant	30.50	24-39	15.03	15.71	91.56	9.04	29.64
Harvest index	35.59	26-41	15.61	18.00	75.20	9.92	27.89

Table 5. Mean performance, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, genetic advance and genetic advance (GA) as per cent of mean for physiological traits under irrigated condition.

Characters	Mean	Range	GCV (%)	PCV (%)	Heritability (h^2_{bs}) (%)	Genetic Advance	Genetic Advance as % Mean
NDVI	0.82	0.79-0.85	1.45	2.15	45.80	0.01	2.02
C.T	17.74	16-20	4.09	4.96	67.85	1.23	6.94
SPAD	46.87	35-54	7.54	8.63	76.24	6.35	13.56

Table 6. Mean performance, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, genetic advance and genetic advance (GA) as per cent of mean for physiological traits under drought condition.

Characters	Mean	Range	GCV (%)	PCV (%)	Heritability (h^2_{bs}) (%)	Genetic Advance	Genetic Advance as % Mean
NDVI	0.77	0.68-0.82	3.15	4.55	47.91	0.03	4.49
C.T	17.92	16-20	2.80	6.90	16.50	0.42	2.34
SPAD	49.15	45-52	3.07	5.41	32.25	1.76	3.59

Table 7. Phenotypic correlation coefficient among yield and yield attributes under irrigated condition.

Characters	DH	DM	PH	SL	PL	T/P	G/S	TGW	BY	HI
DH	1									
DM	0.164	1								
PH	-0.012	0.351**	1							
SL	0.071	0.144	0.192*	1						
PL	-0.070	0.262**	0.674**	0.174	1					
T/P	-0.039	0.078	0.213*	-0.091	0.218*	1				
G/S	0.029	-0.058	0.124	0.309**	0.162	-0.092	1			
TGW	-0.142	0.206*	0.476**	0.003	0.288**	-0.010	0.154	1		
BY	-0.094	0.164	0.492**	0.345**	0.476**	0.371**	0.245**	0.321**	1	
HI	0.395**	-0.023	-0.353**	0.039	-0.344**	-0.246**	0.153	-0.016	-0.338**	1
GY	0.283**	0.096	0.076	0.346**	0.070	0.082	0.371**	0.192*	0.479**	0.596**

* Significant at p= 0.05, ** Significant at p= 0.01

DH-Days to heading, DM-Days to maturity, PH-Plant height (cm), SL-Spike length (cm), PL-Peduncle length (cm), T/P- Effective tillers plant^{-1}, G/S- Grains spike^{-1}, TGW- 1000-grain weight (g), GY-Grains yield plant^{-1} (g), BY-Biological yield plant^{-1} (g), HI-Harvest index (%)

Table 8. Phenotypic correlation coefficient among yield and yield attributes under drought condition.

Characters	DH	DM	PH	SL	PL	T/P	G/S	TGW	BY	HI
DH	1									
DM	0.507**	1								
PH	0.015	0.367**	1							
SL	0.133	0.260**	-0.139	1						
PL	-0.144	0.272**	0.820**	-0.142	1					
T/P	0.229*	0.111	0.029	-0.202*	0.025	1				
G/S	0.271**	0.369**	0.087	0.338**	0.055	-0.104	1			
TGW	-0.342**	0.132	0.476**	-0.067	0.509**	-0.116	0.138	1		
BY	-0.194*	0.146	0.486**	0.201*	0.467**	0.236**	0.090	0.298**	1	
HI	0.137	0.111	-0.137	-0.097	-0.213*	0.110^{NS}	0.173	0.070	-0.280**	1
GY	-0.021	0.233*	0.258**	0.083	0.215*	0.293**	0.229*	0.248**	0.491**	0.619**

* Significant at p= 0.05, ** Significant at p= 0.01

DH- Days to heading, DM- Days to maturity, PH- Plant height (cm), SL- Spike length (cm), PL- Peduncle length (cm), T/P- Effective tillers plant^{-1}, G/S- Grains spike^{-1}, TGW- 1000-grain weight (g), GY-Grains yield plant^{-1} (g), BY-Biological yield plant^{-1} (g), HI-Harvest index (%)

Table 9. Phenotypic correlation coefficient (above diagonal) and genotypic correlation (below diagonal) among yield and yield attributes under irrigated condition for physiological traits.

Characters	NDVI	C.T	SPAD	G/S	TGW	GY
NDVI	1.000	-0.043	-0.044	0.032	-0.095	0.068
C.T	0.041	1.000	-0.004	-0.133	0.048	-0.148
SPAD	-0.106	-0.001	1.000	0.135	0.292**	0.232*
G/S	0.057	-0.228*	0.148	1.000	0.154	0.370**
TGW	-0.148	-0.009	0.404**	0.155	1.000	0.205*
GY	0.141	-0.200*	0.298**	0.476**	0.242**	1.000

* Significant at p = 0.05, ** Significant at p = 0.01

NDVI-Normalized difference vegetation index, C.T- Canopy temperature, SPAD - Soil plant analysis development

Table 10. Phenotypic correlation coefficient (above diagonal) and genotypic correlation (below diagonal) among yield and yield attributes under drought condition for physiological traits.

Characters	NDVI	C.T	SPAD	G/S	TGW	GY
NDVI	1.000	-0.168	0.145	0.093	0.007	0.171
C.T	-0.069	1.000	-0.182*	-0.182*	-0.112	-0.232*
SPAD	0.326**	-0.323**	1.000	0.169	0.027	0.223*
G/S	0.188*	-0.343**	0.480**	1.000	0.161	0.238**
TGW	0.063	-0.364**	0.015	0.125	1.000	0.263**
GY	0.214*	-0.363**	0.394**	0.307**	0.331**	1.000

* Significant at p = 0.05, ** Significant at p = 0.01

NDVI-Normalized difference vegetation index, C.T- Canopy temperature, SPAD - Soil plant analysis development

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