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Variability and interrelationship analysis in bread wheat under moisture stress conditions

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Abstract

A study was undertaken to estimate the genetic variability, correlation and path coefficient analysis of yield and yield contributing traits in 90 wheat cultivars grown under moisture stress. The analysis of variance revealed highly significant differences among varieties for all the traits. The GCV and PCV were high for effective tillers, grain filling duration, grain weight per spike, grains per spike, grain yield, spike length, plant height and days to heading. The genotypic coefficients of the variation for most of the characters were almost equal to its phenotypic coefficient of variation, thereby suggesting predominance of genetic components that was further supported by high heritability estimates for days to heading, days to anthesis, days to physiological maturity, grain filling duration, plant height, spike length and effective tillers. High heritability coupled with high genetic advance was registered for days to heading, grain filling duration, plant height, spike length, effective tillers and grain yield indicated predominance of additive gene action. The significant correlation of harvest index and biological yield with grain yield were recorded, whereas, days to heading had positive and significant correlation with days to anthesis. It is also important to mention that under moisture stress conditions, CT – at grain filling stage had positive and significant association with CT – at anthesis stage but negative and significant association with grain yield. Path analysis revealed that days to physiological maturity, grain weight per spike, harvest index and biological yield had positive direct effects on grain yield; however, days to anthesis and grain filling duration had negative direct effects. It may be concluded that for breeding of water use efficient wheat genotypes, traits like harvest index, biological yield, grain filling duration, grains number and weight per spike need due consideration for yield improvement in wheat.

Keywords: Genetic variability, correlation, path coefficient, bread wheat, water use efficiency

Introduction

Bread wheat (*Triticum aestivum* L. em Thell) is most important cereal crop for the food security. As a staple food, it has got diversified domestic and industrial uses. Wheat provides nearly 55 per cent of the carbohydrates and 20 per cent of the food calories consumed globally (Breiman and Graur, 1995). It exceeds in acreage and production every other grain crop (including rice, maize, etc.) and is therefore, the most important cereal grain crop of the world, which is cultivated over a wide range of climatic conditions. Following the introduction of dwarfing gene (*rht*) based high yielding varieties of spring wheat during 1960s, India witnessed a major breakthrough in wheat grain production and now it is the second most important crop after rice.

Both the stresses (abiotic and biotic) pose limitations to agriculture at global level. Adverse conditions such as drought, higher salt accumulation, excessive temperatures at early and late growth stages, poor soil fertility etc. cause yield losses. In India, among abiotic stresses, drought is a major constraint mainly due to restricted soil moisture and higher temperatures in substantial area. Wheat cultivation in central India is unique wherein two cultivated species *viz., Triticum aestivum* and *Triticum durum* are grown in typical hot tropical climate which is being characterized by the prevalence of high temperatures during different crop growth stages. In this zone, the area under wheat is about 4.89 million hectare with annual production of 10.58 million tons, however, productivity is very low (2164 kg per ha) as compared to the national average of 3140 kilogram per hectare (DWR Report, 2012-13). This is mainly due to the fact that large area of wheat is under rainfed conditions and desired cool climate prevails only for a short period. Very often the crop is exposed to both early and terminal heat stress causing potential yield losses.

The shrinkage of variability in terms of availability of commercially cultivated wheats in Central India is a major concern for wheat breeders. The broad spectrum of central zone comprising several macro and micro-agro-climatic environments, demand an urgent need for expansion of genetic base through diversification of cultivars. The diversification of genotypes needs the augmentation of genetic diversity in wheat germplasm which will act as source for the development of water use efficient genotypes coupled with heat tolerance. Besides, in view the limited availability of irrigation water, breeding for water use efficient genotypes has to become an integral component so as to optimize the wheat yield in traditional cultivation under the multiple cropping systems which are prominent in Central India. Therefore, breeding for water use efficiency in wheat cultivars

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Table 1. Analysis of variance (ANOVA) in bread wheat under moisture stress conditions

Source of variation	DF	Exp	Mean sum of squares													
			Days to heading	Days to anthesis	Days to maturity	Grain filling duration	Plant height	Spike length	Effective tillers	Grains per spike	Grain weight/ spike	1000 grain weight	Harvest index	CT–at anthesis	CT–at grain filling	Biological yield/ plot	Grain yield/ plot
Replication	2	I	9.68	21.25	9.06	5.51	14.94	0.02	734.25	150.71	0.20	10.02	20.45	5.31	7.37	1.53	0.16
	2	II	8.13	2.09	4.43	1.07	0.06	0.02	33.87	65.78	0.18	24.47	9.53	20.21	61.45	0.68	0.19
	2	III	2.92	1.77	3.69	1.48	0.03	0.02	54.25	132.51	0.43	29.70	36.63	1.01	2.61	0.17	0.09
	2	P	14.56	17.19	15.75	0.81	4.87	0.02	492.00	68.70	0.11	31.06	2.75	9.33	23.11	1.70	0.34
Treatment	29	I	148.50**	106.14**	24.26**	55.78**	421.86**	4.53**	854.70**	108.73**	0.29**	59.11**	61.66**	0.53**	2.92**	0.41**	0.15**
	34	II	151.88**	113.56**	29.13**	47.96**	299.46**	4.72**	2348.27**	88.52**	0.17**	64.88**	45.83**	0.87**	4.47**	0.27*	0.12**
	24	III	209.25**	154.25**	211.21**	545.13**	381.05**	2.12**	1886.84**	63.24**	0.18**	36.74**	62.92**	0.99**	7.22*	0.33*	0.13**
	89	P	162.94**	119.53**	89.25**	195.43**	362.28**	3.98**	2008.64**	97.01**	0.24**	54.24**	56.36**	1.48**	6.99**	0.44**	0.17**
Error	58	I	1.10	1.68	1.81	1.36	4.35	0.02	55.78	30.99	0.05	10.13	15.00	0.58	3.46	0.25	0.01
	68	II	2.91	1.72	0.80	1.01	0.93	0.02	3.51	22.66	0.05	15.57	17.68	0.42	1.97	0.21	0.01
	48	III	1.01	1.27	1.26	1.72	0.19	0.03	10.10	17.88	0.03	6.76	20.46	0.42	3.68	0.20	0.02
	178	P	1.81	1.64	1.25	1.38	1.94	0.02	25.96	26.73	0.05	11.46	17.87	0.66	3.42	0.23	0.01
CV (%)		I	1.48	1.66	1.16	3.06	2.14	1.67	8.31	12.58	11.35	6.62	9.62	3.48	6.28	10.85	7.50
		II	2.40	1.69	0.78	2.70	1.01	1.84	1.82	11.85	11.91	8.25	10.77	2.81	4.44	10.88	7.42
		III	1.41	1.46	1.01	3.94	0.45	2.15	2.73	10.48	9.93	5.49	11.80	2.82	6.11	11.20	10.22
		P	1.89	1.65	0.98	3.22	1.44	1.87	4.98	12.43	12.00	7.08	10.77	3.58	5.90	11.03	8.35
CD		I	1.21	1.49	1.55	1.35	2.40	0.17	8.62	6.42	0.28	3.67	4.47	0.88	2.15	0.57	0.16
		II	1.97	1.51	1.03	1.16	1.11	0.19	2.16	5.50	0.26	4.55	4.85	0.75	1.62	0.54	0.14
		III	1.16	1.30	1.29	1.52	0.51	0.21	3.66	4.88	0.22	3.00	5.22	0.75	2.21	0.53	0.18
		P	1.55	1.48	1.29	1.36	1.61	0.19	5.88	5.97	0.27	3.90	4.88	0.94	2.13	0.55	0.16

*, **significant at 5 and 1per cent level, respectively.

requires understanding of the physiological responses of wheat crop to water stress, which may help in identifying traits, to be used as selection criteria. Therefore, present study was conducted to understand the responses of wheat genotypes to water stress and also to find out the genetical behavior of important traits and yield contributing traits.

Materials and methods

The present investigation was carried out at the farm of Indian Agricultural Research Institute, Regional Station, Indore during 2012-13. Geographically, the experimental farm situated between 22°37' N latitude to 75°50' E longitude at 557m above mean sea level has semi-humid and humid climate with temperature range of 23°C to 41°C and 7°C to 29°C in summer and winter seasons, respectively. In this area, most of the rainfall is received during South-west monsoon, *i.e.* between June to September, with occasional showers in winter. The experimental material comprised 90 diverse wheat genotypes planted in three sets (experiment-1, 2 and 3 each having 30, 35 and 25 genotypes, respectively) along with three checks (HI-1500, HI-1531 and HW-2004) in randomized block design (RBD) with three replications. Each genotype was planted in a 6-row plot having a gross area of 6m × 1.20 m, with row to row spacing of 20 cm, while four rows of 5.0 m length were harvested to nullify the border effects. The cultural and agronomic practices recommended for timely sown restricted irrigated conditions were followed to raise the good crop. In order to expose the material to moisture stress, sowings were done in dry field and only two irrigations (first after sowing *i.e.* come up irrigation and second after 35 days of sowing) were given. The observations were recorded on ten randomly selected competitive plants in each replication for plant height (cm), spike length (cm), grains per spike, grain weight per spike, 1000 grain weight (g). Remaining character namely days to heading, days to anthesis, days to physiological maturity, grain filling duration, effective tillers per meter row length, canopy temperature- I (at anthesis stage), canopy temperature-II (at grain filling stage), biological yield per plot (kg) and grain yield per plot (kg) were recorded at plot basis. Further, harvest index was calculated as per the formula reported by Donald and Humbin (1976). Replication wise, mean values of each genotype of all three experiments were pooled and used for statistical analysis. Differences between genotypes for different characters were tested for significance by using Analysis of variance technique (Panse and Sukhatme, 1967). Phenotypic and genotypic coefficients of variation and heritability (in broad sense) by Burton and Vane (1953) and genetic advance were calculated as suggested by Johnson *et al.* (1955). Heritability estimates were categorized as low, moderate and high. Phenotypic correlation and path coefficients were calculated by the formula suggested by Al-Jibouri *et al.* (1958) and Dewey and Lu (1959), respectively.

Results and discussion

From the analysis of variance (Table 1) of all the three experiments, the overall performance of different genotypes and different characters under moisture stress conditions revealed that varietal differences are highly significant for all the characters except biological yield per plot which was significant at 5 per cent level in experiment-1 and 2 and CT-II in experiment-3 at 5 per cent level. In addition, pooled analysis of three experiments revealed that all the treatments were highly significant for all the characters. It was also observed from the results that sufficient variability was present for making selections in all the fifteen characters. This may be because that all the genotypes taken in the study having different genetic base with more genetic variability for all the traits. Such findings were also reported by Ortiz *et al.* (2001), Asif *et al.* (2004), Riaz-Ud-Din *et al* (2010) and Bhushan *et al.* (2013) while studying the agronomic traits in wheat cultivars. In the present investigation, it was found that the testing genotypes having different behaviour under limited water availability which also explains the fact that the characters are highly influenced by water scarcity and/or availability. Similarly, all characters expressed significant interaction with stresses environment which supports that all characters respond to water availability in different ways in different genotypes.

Table 2. Estimates of variation, heritability and genetic advance in bread wheat under moisture stress conditions

Character	Heritability	Genetic advance as % of mean	Coefficient of variation	
			GCV	PCV
Days to heading	0.967	20.86	10.29	10.47
Days to anthesis	0.960	16.29	8.07	8.24
Days to maturity	0.959	9.57	4.74	4.84
Grain filling duration	0.979	44.89	22.03	22.26
Plant height	0.984	23.10	11.30	11.40
Spike length	0.980	26.50	13.02	13.15
Effective tillers	0.962	50.83	25.15	25.64
Grains per spike	0.467	16.37	11.64	17.03
Grain weight per spike	0.519	18.69	12.46	17.30
1000 grain weight	0.555	12.14	7.90	10.61
Harvest index	0.418	12.15	9.13	14.12
CT – anthesis	0.286	2.47	2.26	4.23
CT – grain filling	0.258	3.69	3.53	6.95
Biological yield	0.241	6.25	6.21	12.65
Grain yield	0.709	22.49	13.04	15.48

To find out the pattern and mode of inheritance of fifteen characters, the pooled data was used for analyzing the variation, association and partitioning of association under moisture stress conditions. The success of selection depends on the extent of genetic variability present for a particular character. The higher magnitudes of GCV and PCV in Table 2 were recorded for effective tillers (25.15 and 25.64), grain filling duration (22.03 and 22.26), grain weight per spike (12.46 and 17.30), grains per spike (11.64 and 17.03), grain yield (13.04 and 15.48), spike length (13.02 and 13.15), plant height (11.3 and 11.4) and days to heading (10.29 and 10.47), respectively, suggesting the availability of ample variation for important character grain yield and its components. It was also suggested from the findings that these characters show signs of genetic improvement through objective based selection process. In addition, higher PCV values coupled with moderate or least GCV values were found for the character harvest index, biological yield and 1000 grain weight, however, days to anthesis, days to physiological maturity, CT – anthesis and CT – grain filling exhibited least genotypic and phenotypic coefficient of variation. These findings were in agreement with Yausaf *et al.* (2008), Tripathi *et al.* (2011) and Bhushan *et al.* (2013). Perusal of the Table 2 also indicates that genotypic coefficient of the variation for most of the characters were almost equal to its phenotypic coefficient of variation. This suggests that the major portion of the phenotypic coefficient of variation of these characters was due to genetic causes.

The values of genotypic and phenotypic coefficient of variation solitary are not supportive to predict the behaviour of heritable portion of variation. Lush (1949) elaborated that this fraction of genetic variability is transmitted to generation and coined as heritability. It also expresses the reliability of the phenotypic value as a guide to the breeding value and it indicates the relative success of selection. The high heritability in broad sense estimated for days to heading, days to anthesis, days to physiological maturity, grain filling duration, plant height, spike length, effective tillers and grain yield. Among the higher estimates of heritability, all characters recorded more than 90 per cent except grain yield and it also indicates that higher contribution of genotypic components towards heritability estimates. Similar results for high heritability estimates were presented by Asif *et al.* (2004), Rasal *et al.* (2008), Tripathi *et al.* (2011) and Degewione *et al.*(2013). Whereas moderate values were found for the grains per spike, grain weight per spike, 1000 grain weight and harvest index. Similar results were also reported by Bhushan *et al.* (2013). Character biological yield, CT anthesis and grain filling stages exhibited lower heritability estimates.

It is important to mention that heritability estimates become additional gainful when it also reflected in the form of genetic advance. The expected genetic advance defined as the difference between mean of the progeny of selected individuals and base population which is expressed as per cent of mean. Johnson *et al.* (1955) concluded that heritability estimates without genetic advance does not have realistic value. Therefore, heritability coupled with genetic advance will be more beneficial and these two are complementary concepts (Hanson, 1953). In the present investigation, high heritability coupled with high genetic advance was registered for days to heading, grain filling duration, plant height, spike length, effective tillers and grain yield. This indicates that additive gene action is predominated in these characters expression. On the other hand, high heritability coupled with moderate genetic advance was recorded for days to anthesis and it indicates the presence of additive and non additive gene action. Therefore, days to anthesis could be improved by mass selection and progeny testing based breeding methods. High heritability with low genetic advance was found for days to physiological maturity. Moderate heritability coupled with moderate genetic advance was found for grains per spike, grain weight per spike, 1000 grain weight and harvest index. It is also important to mention that lower heritability coupled with lower genetic advance was recorded for biological yield, CT at anthesis and grain filling stage. Similar results were reported by Prasad *et al.* (2006), Payal *et al.* (2007), Tripathi *et al.* (2011) and Bhushan *et al.* (2013).

Grain yield, a complex and highly variable character is result of cumulative effect of its component traits and therefore, direct selection for yield may not be very efficient. Phenotypic expression is major basis for selection of superior genotypes by the researchers and it is influenced by the environment. Thus, it is necessary to find out the direction and degree of association between two characters. In the present investigation, the major objectives were to understand how the characters are associated amongst themselves and with yield under restricted irrigated conditions. The correlations were estimated to find out the characters which can be given utmost consideration during selection under moisture stress conditions for developing varieties with minimum yield losses under such situation. Phenotypic correlation is the association between two traits that can be directly observed. The positive and significant phenotypic correlation coefficients (Table 3) were recorded for harvest index, biological yield and grain weight per spike with grain yield, however, effective tillers and CT – at grain filling stage had negative and significant association with grain yield.

Character days to heading had positive and significant correlation with days to anthesis and plant height but negative association were found for grain filling duration and harvest index. Whereas days to anthesis exhibited

Table 3. Phenotypic correlation coefficients among fifteen characters in bread wheat under moisture stress conditions

Character	Days to anthesis	Days to maturity	Grain filling duration	Plant height	Spike length	Effective tillers	Grains per spike	Grain weight/ spike	1000 grain weight	Harvest index	CT – at anthesis	CT – at grain filling	Biological yield/ plot	Grain yield/ plot
Days to heading	0.964**	0.077	-0.706**	0.336*	-0.001	0.046	0.156	0.030	-0.207	-0.390**	-0.198	0.001	0.052	-0.291
Days to anthesis		0.077	-0.735**	0.312*	0.015	0.036	0.175	0.061	-0.186	-0.361**	-0.221	-0.026	0.075	-0.243
Days to maturity			0.620**	-0.170	0.116	-0.323*	0.148	0.124	0.002	0.076	-0.091	-0.165	0.105	0.140
Grain filling duration				-0.294	0.067	-0.248	-0.037	0.036	0.148	0.336*	0.112	-0.092	0.013	0.286
Plant height					0.109	0.068	0.084	0.105	0.029	-0.319*	-0.131	-0.021	-0.009	-0.272
Spike length						-0.275	0.353**	0.339*	0.007	-0.107	-0.064	-0.010	0.136	0.017
Effective tillers							-0.308*	-0.329*	-0.044	-0.100	0.130	0.236	-0.263	-0.301*
Grains per spike								0.782**	-0.291	0.054	-0.262	-0.104	0.164	0.195
Grain weight per spike									0.356**	0.089	-0.313*	-0.161	0.245	0.302*
1000 grain weight										0.054	-0.088	-0.096	0.136	0.172
Harvest index											0.063	-0.173	-0.303*	0.632**
CT – at anthesis												0.328*	-0.257	-0.161
CT – at grain filling													-0.279	-0.385**
Biological yield/plot														0.535**

*, ** significant at 5and 1per cent level, respectively.

Table 4. Direct and indirect effects (phenotypic) on grain yield in bread wheat under moisture stress conditions

Character	Days to heading	Days to anthesis	Days to maturity	Grain filling duration	Plant height	Spike length	Effective tillers	Grains per spike	Grain weight/spike	1000 grain weight	Harvest index	CT–at anthesis	CT–at grain filling	Biological yield/ plot
Days to heading	-0.049	-14.860	1.026	13.891	0.003	0.001	0.001	-0.013	0.003	0.010	-0.341	-0.001	0.001	0.041
Days to anthesis	-0.048	-15.423	1.031	1.450	0.002	0.005	0.010	-0.015	0.007	0.009	-0.316	-0.001	0.003	0.059
Days to maturity	-0.004	-1.189	13.370	-12.189	0.001	-0.001	0.030	-0.013	0.014	0.004	0.006	0.020	0.002	0.083
Grain filling duration	0.035	11.331	8.286	-19.668	0.002	0.020	0.005	0.003	0.004	-0.007	0.294	0.010	0.001	0.010
Plant height	-0.017	-4.819	-0.934	5.773	0.008	-0.001	0.009	-0.007	0.012	-0.001	-0.279	-0.001	0.002	-0.007
Spike length	0.020	-0.236	1.550	-1.315	0.001	-0.005	-0.040	-0.030	0.039	0.007	-0.093	0.005	0.004	0.107
Effective tillers	-0.002	-0.548	-4.317	4.870	0.001	0.001	0.020	0.027	-0.038	0.002	-0.087	0.001	-0.002	-0.208
Grains per spike	-0.008	-2.702	1.981	0.730	0.001	-0.002	-0.010	-0.086	0.090	0.014	0.048	-0.001	0.001	0.130
Grain weight per spike	-0.001	-0.940	1.654	-0.712	0.001	-0.002	0.007	-0.067	0.115	-0.017	0.078	-0.001	0.002	0.194
1000 grain weight	0.010	2.866	0.024	-2.901	0.030	0.010	0.009	0.025	0.041	-0.049	0.047	0.005	0.001	0.108
Harvest index	0.019	5.574	1.019	-6.612	-0.003	0.001	0.050	-0.005	0.010	-0.003	0.874	0.007	0.002	-0.240
CT – at anthesis	0.010	3.409	-1.222	-2.202	-0.001	0.001	0.020	0.023	-0.036	0.004	0.055	0.004	-0.003	-0.204
CT – at grain filling	0.001	0.395	-2.211	1.816	0.002	0.002	0.009	0.009	-0.019	0.005	-0.151	0.001	-0.009	-0.221
Biological yield/ plot	-0.003	-1.149	1.407	-0.255	0.040	-0.001	0.006	-0.014	0.028	-0.007	-0.265	-0.001	0.003	0.792

Residual effect: 0.0143; underline values are direct effects positive association with plant height and negative association with grain filling duration and harvest index. Character days to physiological maturity had positive correlation with grain filing duration and negative correlation with effective tillers. Character harvest index had positive association with grain filling duration and grain yield and negative correlation with biological yield, plant height, days to heading and days to anthesis.

Positive and significant associations were found for spike length with grains per spike and grain weight per spike. However, effective tillers exhibited negative and significant association with grains per spike and grain weight per spike under moisture stress conditions. Grain weight per spike had positive and significant association with 1000 grain weight, grains per spike, grain yield and grain weight per spike; however, it also exhibited negative and significant association with effective tillers and CT – at anthesis stage. It is also important to mention that under moisture stress conditions, CT – at grain filling stage had positive and significant association with CT – at anthesis stage but negative and significant association with grain yield.

The results obtained were supported by the reports of Prasad *et al.* (2006), Payal *et al.* (2007), Tripathi *et al.* (2011), El-Mohsen (2012), Singh *et al.* (2012), Fellahi *et al.* (2013), Bhushan *et al.* (2013), Ameen *et al.* (2013) and Gelalcha and Hanchinal (2013). From the foregoing discussions, it can be seen that characters such as biological yield, harvest index, number of grains per spike and grain weight per spike show effective correlations with grain yield and its components traits under restricted irrigation conditions. High positive association of biological yield with grain yield indicates that this character should be given keen importance while breeding for higher yield. The published report supports the results obtained in this investigation. Thus, it can be concluded that the characters biological yield, harvest index, grain filling duration, grains per spike and grain weight per spike should be given utmost consideration during breeding for moisture stress condition in order to minimize the losses in grain yields. Selection for shorter height and earlier maturity could also be effective for the above purpose.

The correlation coefficient does not always give precise information on the contribution of each trait towards dependent variable. To understand the characters which really contribute towards grain yield, the path analysis is obvious. There were many cases in the present study where correlation coefficients of grain yield with the component characters were sufficiently high to establish their importance in selection programme for yield improvement in wheat. But the study of path analysis revealed that they were not so important as merely by seeing the results of correlations. At the phenotypic level of path coefficients (Table-4), days to physiological maturity, grain weight per spike, harvest index and biological yield had higher positive direct effects on grain yield; however, days to anthesis and grain filling duration had negative direct effects on it. The positive path estimates are confirming the extent of association. Similar findings were also reported by Esmail (2001), Payal *et al.* (2007), Tripathi *et al.* (2011), Fellahi *et al.* (2013), Bhushan *et al.* (2013) and Gelalcha and Hanchinal (2013).

It could be concluded that under the stress environments like restricted irrigated conditions, selection of particular trait on the basis of association with trait of interest is difficult; however, partitioning the associations into direct and indirect effects through path analysis provides the appropriate direction for exercising the selection, and it would be helpful to emphasize on harvest index, biological yield, grain filling duration and grains number and weight per spike in future breeding programme.

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