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Genetic variability, correlation and path coefficient analysis in bread wheat (*Triticum aestivum* L.) under normal and moisture-stress conditions

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Abstract

Thirty five genotypes of wheat were evaluated in alpha RBD design for yield and yield contributing traits during *rabi* 2018-19 to find out genetic variability, correlations and direct and indirect effects. Significant genotypic variation was observed for all the 14 quantitative traits studied, indicating considerable amount of variation among genotypes. High heritability and genetic advance were observed for biomass at anthesis under both normal and moisture-stress conditions indicating that these characters are governed by additive gene effects and directional selection for these traits would be more effective. Flag leaf area under both normal and moisture-stress conditions and biomass at tillering under normal conditions exhibited high heritability coupled with moderate genetic advance, indicating moderate expected genetic advance through selection. On the basis of correlation coefficients and path analysis, biomass at maturity and harvest index emerged to be the important selection criteria under both normal and moisture-stress conditions because they had a high direct effect and indirect effect by other traits on grain yield. Grains per spike, biomass at anthesis and stem reserve mobilization also appeared to be the important traits based on their direct or indirect contributions towards grain yield under moisture-stress conditions. Therefore, while exercising selection in wheat under moisture-stress conditions, characters biomass at maturity and harvest index must be given preference.

Keywords: Heritability, genetic advance, correlation, path coefficient

1. Introduction

Wheat (*Triticum aestivum*) 2n=6x=42, is the most important cereal in the world, giving about one-third of the total production, followed closely by rice. In Himachal Pradesh, rainfed cultivation in about 80% area receiving erratic distribution of rainfall during crop season is one of the major constraints responsible for low productivity of wheat. Moreover, moisture-stress is a worldwide issue which predicts the sustainable agricultural production (Jaleel *et al*., 2007).

Drought leads to stomata closure, reduction of water content and turgor loss. Sometime it leads to death of plant by disturbing mobilization (Jaleel *et al*., 2008). It is the most significant environmental stress in agriculture worldwide, which inhibit plant growth and field crops production more than any other environmental stresses (Cattivelli *et al.* 2008). Therefore, identification of genetic variation for important agro-morphological and physiological traits associated with moisture stress tolerance has been a long-standing breeding objective in wheat. The stability of genotypes regarding yield and yield related traits is highly desirable both as cultivar and as source parents for drought tolerance breeding programme.

Correlation is useful in disclosing the magnitude and direction of the relationship between various yield contributing traits and yield. Significant differences for grain yield, 1000-grain weight, biological yield and stem reserve mobilization under water stress conditions have been observed. It has also been found that grain yield has significant correlation with grains per spike, 1000-grain weight, flag leaf area, biomass at maturity and stem reserve mobilization under water stress conditions. While path coefficient measures the direct and indirect effect of a predictor variable upon its response variable and the second component being the indirect effect(s) of a predictor variable (Dewey and Lu, 1959).Therefore, the efforts were made to study the extent of variability, heritability and possible amount of genetic gain expected to occur during the selection for yield improvement.

2. Materials and Methods

The present investigation consisted thirty-five diverse wheat genotypes varying in adaptability and yield potential were evaluated in Alpha-design with 3 replications; each replication further subdivided into seven homogenous blocks both under normal and moisture-stress conditions. Each genotype was grown in 1m x 0.40 m plot with row to row spacing of 20 cm. Standard agronomic practices were followed to raise the crop under both the environments. Total rainfall during the crop season; was 361.5 mm. The minimum and maximum temperature varied from 5.7 °C to 17.1 °C and 21.4 °C to 33.3 °C, respectively. Rainfall was not evenly distributed throughout the crop season; rather it was erratic which resulted in the development of moisture-stress conditions during some stages of plant growth. Crop suffered from intermittent moisture-stress at crown root initiation, tillering, jointing stage and grain filling period. Soil moisture content was determined at anthesis and maturity stage at a depth of 0 - 15 cm and 15 - 45 cm, respectively.

Anthesis stage had soil moisture content i.e. 14.08% (1.28) at 0 - 15 cm depth and 18.42% (1.14) at 15 - 45 cm whereas, at maturity stage soil moisture content was i.e. 11.06% (11.11) and 13.45% (1.48), respectively. Five randomly selected competitive plants from each replication were used for recording the observations on grain yield/plant, grains per spike, thousand grain weight, flag leaf area, days to flowering, days to maturity, plant height, biomass at tillering, biomass at anthesis, biomass at maturity, harvest index and stem reserve mobilization, drought susceptibility index and drought response index was recorded on plot basis.

Statistical analysis

Analysis of variance (ANOVA) was carried out using Parsad *et al.* (2007). The genetic parameters of variability, estimation of heritability and genetic advance were computed according to the method suggested by Burton and DeVane (1953) and Johnson *et al.* (1955). Correlation and path analysis were worked out following the procedure of Al-Jibouri *et al.,* (1958) and Dewey and Lu, (1959).

3. Results and Discussion

3.1 Mean performance

Analysis of variance indicated that the mean squares due to genotypes were highly significant for all the characters both under normal and moisture-stress environments. This indicated the presence of genetic variability in the present material for these characters as evidenced under both the environments. The comparison of mean values for both the environments indicated that there was significant reduction of mean values under moisture-stress as compared to normal conditions for almost all the traits. Reduction percentage in mean values under stress environment over normal environment was highest in biomass at tillering (47.02) followed by biomass at anthesis (32.71), grains per spike (29.18), flag leaf area (26.12) and grain yield/plant (20.29). The least affected character under moisture stress environment was days to flowering (4.15) and harvest index (-0.1) (Table 2).

Estimates of parameters of variability revealed that phenotypic coefficients of variation (PCV) were, in general, higher than their respective genotypic coefficients of variation (GCV) under both the conditions. High PCV (27.15%), GCV (26.05%), heritability (92.04%, 84.51%) and genetic advance (51.48%, 58.14%) were observed for biomass at anthesis under normal and moisture-stress conditions, indicating high genetic variance and genetic advance by exercising selection for this trait under both the environments.

Flag leaf area under both conditions and biomass at tillering under normal conditions exhibited high heritability (89.83%, 82.45%) coupled with moderate genetic advance (43.78%, 43.81%), indicating moderate expected genetic gain through selection under environments. Grains per spike, showed high heritability (95.17%, 89.11%) coupled with low genetic advance was also low (22.07%, 21.13%)

Table.1: Analysis of variance for different traits under non-stress (E1) and moisture-stress (E2) environments in wheat

Traits	Source	Mean sum of squares in E1			Mean sum of squares in E2			
	Replication	Block with in replication E1	Genotype	Error	Replication	Blocks with in replication E2	Genotype	Error
df	2	18	34	50	2	18	34	50
Grain yield/plant (g)	0.05	0.19	1.05**	0.24	0.12	0.06	0.79**	0.11
Grains per spike	0.75	0.75	68.62**	0.51	5.61	1.31	34.13**	1.61
1000-grain weight (g)	0.88	0.41	79.71**	0.66	0.15	0.61	47.85**	0.50
Flag leaf area (cm^2)	4.22	7.43	104.19**	4.50	15.45	6.83	67.09**	4.55
Days to 50% flowering	103.49	0.60	23.52**	0.58	15.62	0.80	61.24**	0.80
Days to 75% maturity	3.89	0.74	27.55**	0.87	16.92	0.37	19.50**	0.76
Plant Height (cm)	74.95	6.80	141.14**	8.67	50.27	0.91	186.79**	0.99
Biomass at tillering (g)	0.88	0.23	3.32**	0.18	2.02	0.24	1.17**	0.31
Biomass at anthesis(g)	20.93	0.53	14.33**	0.47	7.21	0.46	9.91**	0.72
Biomass at maturity(g)	21.96	1.60	3.31**	1.52	124.21	0.65	6.99**	1.92
Harvest index%	175.00	20.11	19.34**	32.15	669.19	20.23	50.59**	17.77
SRM %	191.15	64.73	464.08**	67.75	40.24	48.16	205.15**	41.46

** Significant at 1 per cent level

Table 2: Range, mean and variability parameters for different characters under non-stress (E1) and moisture-stress (E2) environments in wheat

Character	Env.	Range	Mean±S.E.(m)	Percent decrease under stress	PCV %	GCV %	h^2 (bs) %	GA (% of mean)
Grain yield plant^{-1}	E1	3.31-5.76	4.73±0.27		15.98	12.36	59.87	19.71
	E2	2.62-4.70	3.77±0.19	20.29	15.84	13.35	71.06	23.18
Grains spike^{-1}	E1	31.33-56.67	46.06±0.65		11.26	10.98	95.17	22.07
	E2	22.33-37.60	32.62±0.72	29.18	11.51	10.87	89.11	21.13
1000-grain weight	E1	30.50-57.60	45.90±0.39		11.92	11.83	98.42	24.17
	E2	31.87-49.20	40.21±0.42	12.4	10.76	10.61	97.15	21.54
Flag leaf area	E1	15.99-40.86	28.45±1.24		23.66	22.42	89.83	43.78
	E2	13.57-33.25	21.02±1.31	26.12	25.8	23.42	82.45	43.81
Plant height	E1	84.17-118.10	98.29±1.64		7.68	7.11	85.70	13.57
	E2	66.00-104.67	96.14±0.57	12.36	9.66	9.60	98.59	19.63
Days to 50 % flowering	E1	10.3-120.33	114.52±0.44		2.86	2.78	94.49	5.57
	E2	99.3-115.3	109.77±0.50	4.15	4.5	4.43	96.7	8.97
Days to 75% maturity	E1	157.33-173.00	168.68±0.52		2.07	2.00	93.17	3.98
	E2	151.7-165.3	157.81±0.5	6.44	1.89	1.82	92.58	3.60
Biomass at tillering	E1	2.4-7.42	4.53±0.25		27.2	25.35	86.9	48.69
	E2	1.33-3.78	2.40±0.24	47.02	31.08	25.71	68.45	43.82
Biomass at anthesis	E1	4.1-13.11	9.14±0.40		27.15	26.05	92.04	51.48
	E2	3.22-11.00	6.15±0.46	32.71	33.4	30.7	84.51	58.14
Biomass at maturity	E1	12.9-17.67	14.76±0.70		10.00	5.55	30.85	6.35
	E2	8.23-16.20	12.01±0.72	18.63	16.18	12.33	58.01	19.34
Harvest index	E1	22.24-38.37	32.24 ± 2.48		16.2	9.19	32.20	10.74
	E2	22.73-49.34	32.29 ±2.35	-0.1	17.29	11.81	46.63	16.61
SRM	E1	41.56-103.84	80.10±4.73		19.28	16.35	71.94	28.58
	E2	42.26-79.55	65.37±3.79	18.38	15.70	12.06	58.96	19.07

Table 3 Phenotypic correlation coefficients among different characters under normal and moisture-stress environments

Characters	Env.	Grains /spike	1000-Grain weight	Flag leaf area	Days to flowering	Days to maturity	Plant height	Biomass at tillering	Biomass at anthesis	Biomass at maturity	Harvest index	Stem reserve mobilization	DSI	DRI
Grain yield	E1	0.343**	0.386**	0.307**	0.080	-0.104	0.021	0.276**	0.378**	0.326**	.805**	.177	0.389*	-0.000
	E2	.423**	.347**	.283 **	-.501**	-.119	.046	.077	.332**	.487**	.503**	.496**	-0.411*	0.602**
Plant Grains/ spike	E1		0.958**	0.489**	-.004	-.217*	-.048	0.138	0.497**	0.190	.224*	.152	-0.131	0.427**
	E2		.181	.141	-.157	.042	-.082	-.178	.301**	.283**	.131	.389**	-0.209	0.375*
1000-grain weight	E1			0.501**	-0.007	-0.217*	-0.088	0.153	0.529**	0.223*	.248*	.158	-0.103	0.404*
	E2			.121	-.041	.073	.309**	.058**	.378**	.208*	.159	.365**	-0.052	0.207
Flag leaf area	E1				0.001	0.070	-0.057	0.066	0.302**	0.205*	.178	.095	0.261	0.038
	E2				.0139	-.098	.078	.260**	.209*	.203*	.101	.221*	0.031	0.376*
Plant height	E1					0.593**	0.183	-0.179	0.075	-0.117	.172	-.161	0.124	0.056
	E2					.281**	.198*	.156	-.151	-.262**	-.288**	-.198*	0.172	-0.000
Days to flowering	E1						0.186	-0.333**	-0.073	0.014	-.107	-.217*	0.163	-0.003
	E2						-.153	-.126	.002	-.058	-.109	-.158	0.211	-0.128
Days to maturity	E1							0.010	-0.246*	0.161	-.065	-.307**	0.027	0.026
	E2							.386**	.133	.205*	-.156	.131	0.091	0.053
Biomass at tillering	E1								0.392**	0.022	.269**	.062	0.270	-0.152
	E2								.058	.165	-.085	.109	-0.182	0.355*
Biomass at anthesis	E1									0.200*	.275**	.176	-0.028	0.180
	E2									.267**	.027	.316**	-0.364*	0.527**
Biomass at maturity	E1										-.289**	-.021*	0.248	-0.057
	E2										-.483**	.322**	-0.076	0.354*
Harvest Index	E1											0.187	1.65	-0.32
	E2											0.190	-0.072	0.43**
Stem reserve Mobiliza-tion	E1												-0.099	0.089
	E2												-0.402*	0.637**
DSI	E1													-0.766**
	E2													-0.766**

under both normal and moisture-stress E1 and E2, respectively (Table 2).

Similarly, thousand-grain weight exhibited low value for PCV (11.92%, 10.76%) and GCV (11.83%, 10.61%) both under normal and moisture-stress conditions, respectively. Heritability exhibited high values (98.42, 97.15) both under normal and moisture-stress environments. However, genetic advance estimates were found to be low (24.17% and 21.54%) both under normal and moisture-stress. Moderate heritability (68.45%, 58.96%) and genetic advance (43.82%, 19.07%) were exhibited by biomass at tillering under moisture-stress and stem reserve mobilization under non stress conditions under non stress conditions (Table.2).

3.2 Correlation Analysis

Correlation analysis (Table 3) revealed that theat phenotypic level, grain yield had a significant positive correlation with grains per spike, 1000- grain weight, flag leaf area, biomass at tillering, biomass at anthesis, biomass at maturity, harvest index and drought susceptibility index under non-stress environment (Table 4.4). Under moisture-stress environment, grain yield showed negative correlations with days to 50% flowering and drought susceptibility index, while it had positive significant correlations with grains per spike, 1000- grain weight, flag leaf area, biomass at anthesis, biomass at maturity, harvest index, stem reserve mobilization and drought response index (DRI). Under non-stress environment, 1000-grain weight had positive association with flag leaf area, biomass at anthesis, biomass at maturity, harvest index and drought response index, whereas, it had negative correlation with days to 75% maturity. Under moisture-stress environment, it showed positive correlation with plant height, biomass at tillering, biomass at anthesis, biomass at maturity and stem reserve mobilization. Thousand-grain weight had positive association with flag leaf area, biomass at tillering, biomass at anthesis, biomass at maturity, harvest index and stem reserve mobilization, whereas, it had negative correlation with days to 50% flowering, days to 75% maturity and plant height under non-stress environment.

Flag leaf area had positive correlation with biomass at anthesis and biomass at maturity under non-stress environment. Whereas under moisture-stress conditions, flag leaf area had positive correlation with biomass at tillering, biomass at anthesis, biomass at maturity, stem reserve mobilization and drought response index (Table 4.4). Under non-stress conditions, plant height had positive correlation with days to maturity. Whereas under moisture-stress environment, it had positive correlation with days to maturity and a significant negative correlation with biomass at maturity, harvest index and stem reserve mobilization.

Days to flowering showed negative correlation with biomass at tillering and stem reserve mobilization under non-stress environment, while this character didn't exhibit any significant correlation with other traits under moisture-stress conditions. Under normal conditions, days to maturity was negatively correlated with biomass at anthesis and stem reserve mobilization. It had positive correlation with biomass at tillering and biomass at maturity under moisture-stress conditions.

Biomass at maturity showed significant negative correlation with harvest index and stem reserve mobilization under normal conditions, while it had positive correlation with stem reserve mobilization and drought response index and negative correlation with harvest index under moisture-stress conditions. Under moisture-stress conditions, harvest index showed significant positive correlation with drought response index. Srivastava *et al.* (2017) studied that percent reduction in 1000 grain weight rank from 4.45 to 39.6% under irrigated condition and 32.4-35.0 % under drought conditions. They reported a significant correlation between stem reserve mobilization and length of peduncle. They also pointed out that varieties with good stem reserve mobilization based on 1000-weight of grain in absence of photosynthesis may exhibit tolerance to moisture-stress.

Drought susceptibility index was negatively correlated to drought response index under both, normal and moisture-stress conditions. Patel *et al.* (2019) evaluated various drought tolerance/resistance indices and concluded that these indices were more effective in identifying high yielding lines under drought stress as well as non-stress conditions. They reported significant and positive correlation of yield potential under normal (Y_P) and yield under stress (Y_S) which indicated that high yield performance under normal conditions resulted in relatively high yield under stress conditions.

3.3 Path Analysis

Data presented (Table 4) revealed that characters under normal environment, significant positive correlation of grains per spike with grain yield was mainly due to high positive indirect effect via harvest index and biomass at maturity, high direct effect of grains per spike on grain yield. However, under moisture-stress environment, grains per spike exhibited high positive direct effect along with biomass at maturity, biomass at anthesis, whereas rest of the indirect effects were lower in magnitude. Under normal environment, 1000 grain weight had significant correlation with grain yield and also positive indirect effect via grains per spike and harvest index. Positive indirect effects via other traits were partially counter balanced by the high negative indirect effect via days to maturity at phenotypic level. Under moisture-stress environment, 1000 grain weight had negative direct effect on grain yield and also indirect effect via biomass at maturity and biomass at anthesis. While indirect effect via other traits were of low magnitude. Srivastava *et al.* (2017) studied that percent reduction in 1000 grain weight rank from 4.45 to 39.6% under irrigated condition and 32.4-35 % under drought conditions. They concluded that the significant correlation between stem reserve mobilization and length of peduncle. They also pointed out that varieties with good stem reserve mobilization based on 1000 weight of grain in absence of photosynthesis may exhibit tolerance to moisture-stress.

Important traits biomass at maturity had highest positive direct effect on grain yield and also positive indirect effects via grains per spike under normal conditions. It also exhibited low magnitude of negative indirect effects via 1000 grain weight and plant height. However, under moisture-stress conditions, positive correlation of biomass at maturity with grain yield was mainly because of high positive direct effect and high positive indirect effects via biomass at anthesis and grains per spike. Biomass at maturity also exhibited high positive indirect effect of

Table 4 Estimates of direct and indirect effects of different characters at phenotypic level under normal and moisture-stress environment

Characters	Env.	Grain /Spike	1000 Grain weight	Flag leaf area	Days to flowering	Days to maturity	Plant height	Biomass at tillering	Biomass at anthesis	Biomass at maturity	Harvest index	SRM	Correlation with grain yield
Grains per spike	E1	0.037	-0.015	0.001	0.000	-0.003	0.001	0.001	-0.017	0.117	0.221	0.000	0.343**
	E2	0.017	-0.007	-0.003	-0.005	0.002	0.000	-0.001	0.020	0.273	0.129	0.000	0.424**
1000-grain weight	E1	0.035	-0.016	0.001	0.000	-0.003	0.002	0.001	-0.018	0.137	0.245	0.000	0.386**
	E2	0.003	-0.039	-0.003	-0.001	0.003	0.002	0.000	0.025	0.200	0.157	0.000	0.348**
Flag leaf area	E1	0.018	-0.008	0.002	0.000	0.001	0.001	0.001	-0.010	0.126	0.176	0.000	0.307**
	E2	0.002	-0.005	-0.023	0.000	-0.004	0.000	0.002	0.014	0.196	0.100	0.000	0.284**
Days to flowering	E1	0.000	0.000	0.000	-0.017	0.007	-0.004	-0.002	-0.003	-0.072	0.170	0.000	0.080
	E2	-0.003	0.002	0.000	0.034	0.010	0.001	0.001	-0.010	-0.252	-0.284	0.000	-0.501**
Days to maturity	E1	-0.008	0.003	0.000	-0.010	0.012	-0.004	-0.003	0.003	0.009	-0.105	0.000	-0.104
	E2	0.001	-0.003	0.002	0.010	0.037	-0.001	-0.001	0.000	-0.056	-0.108	0.000	-0.120
Plant height	E1	-0.002	0.001	0.000	-0.003	0.002	-0.021	0.000	0.009	0.099	-0.064	-0.001	0.021
	E2	-0.001	-0.012	-0.002	0.007	-0.006	0.006	0.003	0.009	0.198	-0.154	0.000	0.047
Biomass at tillering	E1	0.005	-0.002	0.000	0.003	-0.004	0.000	0.009	-0.014	0.013	0.266	0.000	0.276**
	E2	-0.003	-0.002	-0.006	0.005	-0.005	0.002	0.007	0.004	0.159	-0.084	0.000	0.077
Biomass at anthesis	E1	0.018	-0.008	0.001	-0.001	-0.001	0.005	0.003	-0.035	0.123	0.272	0.000	0.377**
	E2	0.005	-0.015	-0.005	-0.005	0.000	0.001	0.000	0.066	0.258	0.026	0.000	0.332**
Biomass at maturity	E1	0.007	-0.004	0.001	0.002	0.000	-0.003	0.000	-0.007	0.616	-0.286	0.000	0.326**
	E2	0.005	-0.008	-0.005	-0.009	-0.002	0.001	0.001	0.018	0.962	-0.476	0.000	0.488**
Harvest index	E1	0.008	-0.004	0.000	-0.003	-0.001	0.001	0.002	-0.010	-0.178	0.989	0.000	0.805**
	E2	0.002	-0.006	-0.002	-0.010	-0.004	-0.001	-0.001	0.002	-0.464	0.987	0.000	0.503**
SRM	E1	0.006	-0.003	0.000	0.003	-0.003	0.006	0.001	-0.006	-0.013	0.185	0.002	0.178
	E2	0.007	-0.014	-0.005	-0.007	-0.006	0.001	0.001	0.021	0.311	0.188	0.001	0.496**

lower magnitude via biomass at tillering and plant height. Dorin *et al.* (2007) studied that highest positive direct effect of biological yield on grain yield followed by harvest index, leaf area and days to heading. Simple correlation analysis coupled with path analysis, therefore, suggested that 1000 grain weight and biological yield are the traits of greater importance for improving drought tolerance. Another important trait, harvest index had highest positive direct effect on grain yield and also positive indirect effects via grains per spike under normal conditions. It also exhibited low magnitude of negative indirect effects via biomass at tillering and plant height. However, under moisture-stress conditions, positive correlation of harvest index with grain yield was mainly because of high positive direct effect and high positive indirect effects via grains per spike. It also exhibited high positive indirect effect of lower magnitude via biomass at anthesis. Stem reserve mobilization had positive correlation with grain yield under moisture-stress conditions was mainly due to high positive direct effect and indirect effects via harvest index. This could be attributed to the higher accumulation of photosynthates, vegetative one due to longer heading duration. Noorka *et al.* (2013) reported that stem reserve mobilization was an important index of moisture stress tolerance. A genotype having high capacity to mobilize its reserves may be considered to show good performance under moisture-stress conditions.

4. Conclusion:

The present study revealed that high heritability and genetic advance were observed for biomass at anthesis under normal and moisture-stress conditions indicating importance of this trait for selection. Flag leaf area under normal and moisture-stress and biomass at tillering under normal conditions exhibited high heritability coupled with moderate genetic advance, indicating moderate expected genetic gain through selection under environments. Based on correlation coefficient and path analysis, biomass at maturity and harvest index emerged to be the important selection criteria under both normal and moisture-stress conditions because they had a high direct effect and indirect effect by other traits on grain yield. Grains per spike, biomass at anthesis and stem reserve mobilization also appeared to be the important traits based on their direct or indirect contributions towards grain yield under moisture-stress conditions. These traits can be used in breeding programme to develop drought tolerant genotypes.

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