http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 3 (1): 72-77, 2000

Correlation and Path Coefficient Analysis in Bread Wheat under Drought Stress and Normal Conditions

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Abstract: This paper describes the association, direct and indirect effects of morphological traits under drought stress and irrigated conditions. Significant mean squares among crosses were obtained for all characters under irrigation as well as drought stress. Positive and significant correlations were observed between grain yield per plant and flag leaf area, specific flag leaf weight, tillers per plant, peduncle length, spike length, grains per spike, 1000-grain weight, grain weight of mother shoot, biomass per plant and harvest index. Negative and significant correlation was noted for days to heading and grain yield per plant. Positive direct effects were exhibited for specific flag leaf weight, days to heading, tillers per plant, spikelets per spike, grain weight of mother shoot, biomass per plant and harvest index on grain yield while maximum indirect effects were observed through grain weight of mother shoot on grain yield for flag leaf area, days to heading, peduncle length, spike length, grains per spike, 1000-grain weight, biomass per plant and harvest index under irrigated conditions. In case of drought stress conditions, grain yield was positively and significantly correlated with flag leaf area, specific flag leaf weight, plant height, peduncle length, spike length, grains per spike, 1000-grain weight, grain weight of mother shoot, biomass per plant and harvest index. Similar to irrigated conditions days to heading has also negative and significant correlation with grain yield. Positive direct effects were observed for leaf venation, flag leaf area, days to heading, plant height, spike length, grains per spike, 1000-grain weight, biomass per plant and harvest index whereas positive indirect effects through biomass per plant on grain yield for leaf venation, plant height, spike length, grains per spike, 1000-grain weight, grain weight of mother shoot were observed under drought stress conditions. It is suggested that direct selection could be made for days to heading, tillers per plant, spikelets per spike, grain weight of mother shoot, biomass per plant and harvest index for the improvement of grain yield per plant and indirect selection through grain weight of mother shoot for spike length, grains per spike 1000-grain weight under irrigated conditions. Under drought stress conditions selection could be made for leaf venation, flag leaf area, days to heading, plant height, spike length, grains per spike, 1000-grain weight, biomass per plant and harvest index and indirect selection via biomass per plant for leaf venation, plant height, spike length, grains per spike, 1000-grain weight and grain weight of mother shoot.

Key words: Wheat, drought stress, genetics correlation, path-coefficient analysis

Introduction

For evolving varieties suitable for cultivation in irrigated as well as in drought-prone areas, knowledge of the correlation between component characters is a pre-requisite as the characters might be differently correlated among themselves. Several studies involving genetic correlation and path coefficient analysis have been conducted in wheat. Dornescu (1986) reported that grain weight per main spike, 1000-grain weight and grains per plant had direct effect on grain weight per plant. Number of grains per main spike had important indirect effect via grain weight per main spike. Similarly, Sheoran *et al.* (1986) reported that yield was strongly and positively correlated with spike length, grains per spike, plant height and flag leaf area. Path analysis revealed that selection of rainfed wheat may be based on 1000-grain weight and grains per spike. However, Bangarwa *et al.* (1987) revealed that grain yield per plant was highly and positively correlated with spikes per plant, plant height, spikelets per spike, spike length and biological yield per plant. Biological yield per plant and spike length made the maximum contribution to grain yield, as exhibited by path analysis and were recommended as selection criteria for improving grain yield. Similarly, Atale and Zope (1988) reported that yield was significantly and positively correlated with biomass per meter, grain weight per ear and grains per ear under both environments. Under high fertility conditions, grains per ear, grain weight per ear, ears per meter, ear length and biomass per meter had positive direct effect on yield while under low fertility conditions grain weight per ear and ears per meter did so. Bessonova (1988) observed that the length of the upper most internode was positively correlated with grain weight per ear. Selection based on this criterion from the milk stage to ripe stage was effective. Similarly, Krotova (1988) reported that yield per plant was closely correlated with number of fertile tillers and yield of main ear. A high and significant correlation was found between yield per main ear and grains per main ear and grain size. Srivastava *et al.* (1988) revealed that yield was positively and significantly correlated with harvest index, biological yield, grain weight per spike, spikes per plant and flag leaf area. Biological yield, harvest index and days to anthesis had high direct effects on yield. (Qian *et al.* (1989) revealed that 1000-grain weight had the most important direct effect on yield, followed by plant height, grains per ear and ears per plant. Whereas Singh *et al.* (1990) reported that significant positive correlation of total biomass with grain yield, number of tillers and grains per spike were recorded. Total biomass produced the highest consistent direct and indirect effect on grain yield. Therefore, total biomass was suggested to be the main selection parameter in breeding dry land wheat varieties.

Sharma and Singh (1991) revealed that path coefficient analysis showed that harvest index, biological yield and tiller number were the most important contributors to yield. Wang *et al.* (1991) reported that grain number and weight of main spike, 100-grain weight and fertile spikelets but not plant height, spikes per plant and spike length were significantly correlated with grain yield per plant. Path analysis showed that the direct contribution of grain weight of main spike to grain yield per plant was highest followed by spikes per plant in both areas. Whereas Ahmad *et al.* (1994) reported positive and significant genotypic correlation among productiVe tillers/ m^2, spike length, grains per spike and grain yield. Path analysis showed that productive tillers/m^2 had maximum positive direct effect on grain yield. Grains per spike had negative direct effect on grain yield.

The objectives of the current study were to i) worked out the correlatrions among yield, morpho-physiological traits, ii) determine the direct and indirect effects of morpho-physiological traits on grain yield, of bread wheat grown under irrigated and rainfed areas so as to work out a suitable trait which could be used for yield improvement under both conditions.

Materials and Methods

The thirty F_1's including reciprocals and their six parents were space planted in randomized complete block design with three replications during the year 1995-96 in the research area of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The experimental plot was a four meter single row having 27 plants. The rate of seeding was two seeds per hill and later thinned to one plant per site with a distance of 15 centimeters within rows and 30 centimeters between rows. For two sets of experiments, one under regular irrigation and the other under zero irrigation (drought stress), the fields were irrigated for seed bed preparation. After planting of experimental population, four canal irrigations were applied to normal experiment during the active growing period. Whereas the other experiment entirely depended on natural precipitation and no surface irrigation was applied to drought experiment for maintaining moisture stress conditions. Only a very little amount of rainfall (35 mm) was received during the experimental period (November to April). Fertilizer was applied at planting time at the rate of 100 kg N and 75 kg P per hectare. Fertilizer application rates were identical for both environments. The crop was kept free from weeds. Measurements were made on only competitive plants under both environments for morpho-physiological traits like stomatal frequency, leaf venation, flag leaf area (cm^2), specific flag leaf weight (mg/cm^2), days to heading, tillers per plant, plant height (cm), peduncle length (cm), spike length (cm), spikelets per spike, grains per spike, 1000-grain weight (g), grain weight of mother shoot (g), biomass per plant (g), grain yield per plant (g) and harvest index.

Components of variances and covariances were estimated for individual environment (irrigated and drought stress conditions) data according to method of Steel and Torrie (1980). All main effects and interaction effects in the analysis of variance were considered random.

Coefficient of genotypic variation (CVg), which allows us to compare genetic variability among traits with different measurement units, was obtained as follows:

$$CV_g = \frac{\sqrt{Var_{gi}}}{X_i} \times 100$$

where Var_{gi} is genotypic variance for the ith trait and calculated using the appropriate genotypic (G) and genotypic x environment (G X E) mean squares from the analysis of variance and X_i represents the mean of genotypes for ith trait.

Heritability was calculated as a ratio between genotypic and phenotypic variances (Burton and Devane, 1953).

$$H = \frac{Var_{gi}}{Var_p} \times 100$$

Genetic (r_g) correlation between ith and jth traits were calculated with the method outlined by Falconer (1981).

$$rg_{ij} = \frac{COV_{g_{ij}}}{\sqrt{Var_{gi} \times Var_{gj}}}$$

where $COVg_{ij}$ is a genotypic covariance between traits I & j. The significance of genetic correlation coefficient (r_g) was checked against the formula given below by Reeve (1955) and Robertson (1959).

$$S.E.\ of\ re_g = \frac{1-(r_g)^2}{\sqrt{2}} \sqrt{\frac{\sqrt{h^2x}}{h^2x} - \frac{\sqrt{h^2y}}{h^2y}}$$

Path coefficient analysis was done according to Dewey and Lu (1959). Path coefficient analysis has been used in determining selection criteria in many crops such as wheat and some other crops. With path coefficient (p) analysis, the direct effect of a independent variable (x1, x2,... xn) on the dependent variable trait (y) can be determined. Path coefficient analysis were computed using genotypic correlation. In this case, it is assumed that each of the independent variables has a direct effect on the dependent variable (grain yield).

Results and Discussion

The genotypic differences were highly significant for all the characters under both environments except harvest index which is only significant under drought stress conditions. This confirmed the presence of variability in the material grown under irrigated and drought stress conditions.

Irrigated conditions: Genotypic correlation: The genotypic correlation for stomatal frequency with grain yield was negative and non-significant (above the diagonal in Table 1). Also, direct effects of stomatal frequency on grain yield were small and negative with a value of -0.2973 (Table 2). This indicates that breeding for more stomata frequency on adaxial surface of the leaf will not affect progress in grain yield improvement. Significant genotypic associations were observed for stomatal frequency with leave venation, flag leaf area, days to heading, plant height and spikelets per spike. Whereas significant and negative correlation coefficients were noted with specific flag leaf area, tillers per plant and harvest index. Leaf venation was significantly and positively correlated with days to heading, spikelets per spike and grains per spike. Flag leaf area positively and significantly correlated with plant height, peduncle length, spike length, 1000-grain weight, grain weight of mother shoot, biomass per plant, harvest index and grain yield per plant. Significant genotypic correlation occurred for flag leaf area and grain yield under irrigated conditions, which agrees with the statement of Sheoran *et al.* (1986) and Srivastava *et al.* (1988) that grain yield was positively and significantly correlated with flag leaf area. Specific flag leaf weight was also positively and significantly associated with tillers per plant, peduncle length, spike length, 1000-grain weight, grain weight of mother shoot, biomass per plant and grain yield per plant. Days to heading significantly associated with spikelets per spike and grains per spike, but negative and significant correlation was observed for days to heading with peduncle length, spike length, 1000-grain weight, grain weight of mother shoot, biomass per plant, harvest index and grain yield per plant. Under irrigated conditions, tillers per plant was positively and significantly correlated with biomass per plant (Singh *et al.,* 1990), harvest index and grain yield per plant (Krotova, 1988; Ahmad *et al.* 1994). Plant height was also positively and significantly associated with peduncle length, spike length, 1000-grain weight, grain weight of mother shoot. Positive and significant correlations were observed for peduncle length with spike length, 1000-grain weight, grain weight of mother shoot (Bessonova, 1988) biomass per plant and grain yield per plant. Similarly, positive and significant association was observed between spike length and 1000-grain weight, grain weight of mother shoot, biomass per plant and grain yield per plant. These results are in agreement with the findings of Sheoran *et al.* (1986), Bangarwa *et al.* (1987) and Ahmad *et al.* (1994), who reported that spike length was positively and significantly associated with grain yield. Spikelets per spike positively and significantly correlated with grains per spike. Grains per spike was positively and significantly associated with grain weight of mother shoot (Krotova, 1988), biomass per plant (Singh *et al.,* 1990), harvest index and grain yield per plant (Sheoran *et al.,* 1986; Wang *et al.,* 1991; Ahmad *et al.,* 1994), while negative and significant association exhibited with 1000-grain weight. Positive and significant association was noted for 1000-grain weight with grain weight of mother shoot (Krotova, 1988), biomass per plant and grain yield per plant (Wang *et al.,* 1991). Similarly, positive and significant correlations were observed between grain weight of mother shoot and biomass per plant, harvest index and grain yield per plant. Biomass per plant had positive and significant correlation with harvest index and grain yield per plant (Singh *et al.,* 1990). Harvest index also had significant correlation with grain yield per plant. Results of Srivastava *et al.* (1988) showed a positive and significant correlation between harvest index and grain yield.

Path-coefficient analysis: Stomatal frequency produced negative direct effect on grain yield, while positive indirect effects on grain yield was noted through days to heading, spikelete per spike, grains per spike and grain weight of mother shoot (Table 2). Leaf venation also exhibited negative direct effect on grain yield, but this was compensated by days to heading, spikelets per spike, 1000-grain weight and biomass per plant under irrigated conditions. Similarly, flag leaf area also showed the negative direct effect and maximum positive indirect effects were observed through grain weight of mother shoot, grains per spike, biomass per plant and harvest index. Specific flag leaf weight indicates the positive direct effect and maximum positive indirect effect was noted through grain weight of mother shoot and followed by biomass per plant. Similarly, days to heading had positive direct effect and positive indirect effect was recorded through 1000-grain weight. Tillers per plant showed positive (0.2262) direct effect (Atale and Zope, 1988; Sharma and Singh, 1991) and positive indirect effect via 1000-grain weight was noted on grain yield (Ahmad *et al.,* 1994) and followed by biomass per plant. Under irrigated conditions plant height had negative direct effect while compensated grain yield per plant by the indirect effects through grain weight of mother shoot and grains per spike. Similarly, peduncle length and spike length showed negative direct effect and positive indirect effect was noted via grain weight of mother shoot on grain yield. Spike length and spikelts per spike has positive direct effects on grain yield under irrigated conditions. Grains per spike has negative direct effect on grain yield but this was compensated by the positive indirect effect through grain weight of mother shoot and followed by 1000-grain weight. Similarly, 1000-grain weight showed negative direct effect on grain yield while positive and maximum indirect effect was via grain weight of mother shoot and followed by grains per spike. Grain weight of mother shoot had the maximum direct effect on grain yield and positive indirect effect was observed via biomass per plant. Positive direct effect was also observed for biomass per plant on grain yield and positive indirect effect through grain weight of mother shoot. Harvest index had positive direct effect and positive indirect effect via grain weight of mother shoot followed by biomass per plant on grain yield.

Drought stress conditions: Genetic correlation.: Correlation coefficients between grain yield and morpho-physiological traits under drought stress conditions are presented below the diagonal in Table 1. Stomatal frequency was positively

Table 1: Genotypic correlation coefficients of stomatal frequency (SF), leaf venation (LV), flag leaf area (FLA), specific flag leaf weight (SFLW), days to heading (DH), tillers per plant (TP), plant height (PH), peduncle length (PDL), spike length (SL), spikelets per spike (SS), grains per spike (GS), 1000-grain weight (GW), grain weight of mother shoot (GWMS), biomass per plant (BP), grain yield per plant (GY) and harvest index (HI) in a 6 x 6 diallel cross under irrigated (above diagonal) and drought stress (below diagonal) conditions

	SF	LV	FLA	SFLW	DH	TP	PH	PDL	SL	SS	GS	GW	GWMS	BP	HI	GY
		0.521*	0.305*	-0.357*	0.314*	-0.351*	0.4-97*	-0.060	-0.028	0.435*	-0.209	0.156	0.024	-0.043	-0.318*	-0.168
	0.155*		-0.053	-0.254*	0.688*	-0.035	0.212	-0.175	-0.127	0.846*	0.489*	-0.346*	0.012	0.120	-0.317*	-0.046
	0.460*	0.015		0.092	-0.461*	-0.305*	0.839*	0.643*	0.579*	0.097	-0.067	0.914*	0.829*	0.524*	0.439*	0.640*
V	0.093	0.712*	0.426*		-0.690*	0.250*	-0.092	0.571*	0.691*	-0.471*	-0.181	0.479*	0.343*	0.489*	0.064	0.454*
	-0.175*	0.820*	-0.233*	0.667*		-0.101	0.046	-0.413*	-0.508*	0.816	0.451*	-0.653*	-0.349*	-0.226*	-0.310*	-0.347*
	-0.119	0.201	-1.415*	-0.048	0.324*		-0.502*	-0.128	-0.005	0.018	0.146	-0.306*	-0.214*	0.658*	0.421*	0.688*
	0.680*	0.332*	0.809*	0.375*	-0.142	-1.005*		0.659*	0.474*	0.141	-0.290*	0.602*	0.384*	0.117	-0.321*	-0.060
	0.087	-0.320*	0.664*	-0.082	-0.661*	-1.035*	0.643*		0.921*	-0.231	-0.211*	0.719*	0.556*	0.548*	-0.093	0.396*
	0.167	0.291*	0.201*	0.243*	-0.215*	-0.565*	0.679*	0.682*		-0.237	-0.082	0.757*	0.673*	0.672*	0.160	0.601*
	-0.021	1.117	-0.348*	0.745*	0.857*	0.096	0.101	-0.410*	0.244*		0.649*	-0.365*	0.068	0.204	-0.207	0.165
	0.032	0.769*	0.103	0.390*	0.393*	-0.466*	0.551*	0.234*	0.571*	0.703*		-0.257*	0.384*	0.350*	0.493*	0.440*
	0.350*	-0.443*	0.945*	0.034	-0.634*	-0.727*	0.817*	0.866*	0.558*	-0.328*	-0.037		0.792*	0.464*	0.127	0.454*
IS	0.311	0.127	0.839*	0.267*	0.266*	0.904*	0.994*	0.835*	0.800*	0.167*	0.588*	0.783*		0.652*	0.429*	0.700*
	0.081	0.236*	0.196	0.454*	-0.016	0.070	0.549*	0.432*	0.609*	0.350*	0.356*	0.475*	0.588*		0.344*	0.966*
	-0.087	-0.711*	1.245*	-0.275*	-0.896*	-0.973*	0.853*	0.905*	0.340*	-0.320*	0.052	0.848*	0.699*	0.059		0.687*
	0.027	0.012	0.375*	0.304*	-0.243*	-0.037	0.688*	0.616*	0.591*	0.150	0.311*	0.602*	0.658*	0.970*	0.363*	

Table 2: Path-cofficiecnt of stomatal frequency (SF), leaf venation (LV), flag leaf area (FLA), specific flag leaf weight (SFLW), days to heading (DH), tillers per plant (TP), plant height (PH), peduncle length (PDL), spike length (SL), spekelets per spike (SS), grains per spike (GS), 1000-grain weight (GW), grain weight of mother shoot (GWMS), biomass per plant (BP), grain yield per plant (GY) and harvest index (HI) in a 6 x 6 diallel cross under irrigated conditions.

	SF	LV	Fla	SFLW	HD	TP	PH	PDL	SL	SS	GS	GW	GWMS	BP	HI	r_g
		0.521*	0.305*	-0.357*	0.314*	-0.351*	0.497*	-0.060	-0.028	0.435*	-0.209	0.156	0.024	-0.043	-0.318*	-0.168
	0.155		-0.053	-0.254*	0.688*	-0.035	0.212	-0.175	-0.127	0.846*	0.489*	-0.346*	0.012	0.120	-0.317*	-0.046
	0.460*	0.015		0.092	-0.461*	-0.305*	0.839*	0.643*	0.579*	0.097	-0.067	0.914*	0.829*	0.524*	0.439*	0.640*
V	0.093	0.712*	0.426*		-0.690*	0.250*	-0.092	0.571*	0.691*	-0.471*	-0.181	0.479*	0.343*	0.489*	0.064	0.454*
	-0.175*	0.820	-0.233	0.667*		-0.101	0.046	-0.413*	-0.508*	0.816	0.451*	-0.653*	-0.349*	-0.226*	-0.310*	-0.347*
	-0.119	0.201	-1.415*	-0.048	0.324*		-0.502*	-0.128	-0.005	0.018	0.146	-0.306*	-0.214*	0.658*	0.421*	0.688*
	0.680*	0.332*	0.809*	0.375*	-0.142	-1.005*		0.659	0.474*	0.141	-0.290*	0.602*	0.384*	0.117	-0.321*	-0.060
	0.084	-0.320*	0.664*	-0.082	-0.661*	-1.035*	0.643*		0.921*	-0.231	-0.211*	0.719*	0.556*	0.548*	-0.093	0.396*
	0.167	0.291*	0.201*	0.243*	-0.215*	-0.565*	0.679*	0.682*		-0.237	-0.082	0.757*	0.673*	0.672*	0.160	0.601*
	-0.021	1.117	-0.348*	0.745*	0.857*	0.096	0.101	-0.410	0.244*		0.649*	-0.356*	0.068	0.204	-0.207	0.165
	0.032	0.769*	0.103	0.390*	0.393*	-0.466*	0.551*	0.234*	0.571*	0.703*		-0.257*	0.384*	0.350*	0.493*	0.440*
	0.350*	-0.443*	0.945*	0.034	-0.634*	-0.727*	0.817*	0.866*	0.558*	-0.328*	-0.037		0.792*	0.464*	0.127	0.454*
MS	0.311	0.127	0.839*	0.267*	-0.266*	-0.904*	0.994*	0.835*	0.800*	0.167*	0.588*	0.783*		0.652*	0.429*	0.700*
	0.081	0.236*	0.196	0.454*	-0.016	0.070	0.549*	0.432*	0.609*	0.350*	0.356*	0.475*	0.588*		0.344*	0.966*
	-0.087	-0.711	1.245*	-0.275*	-0.896*	-0.973*	0.853*	0.905*	0.340*	-0.320	0.052	0.848*	0.699*	0.059		0.687*
	0.027	0.012	0.375*	0.304*	-0.243*	-0.037	0.688*	0.616*	0.591*	0.150	0.311*	0.602*	0.658*	0.970*	0.363*	

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Table 3: Perth-coefficients of stomatal frequency (SF), leaf venation (LA), flag leaf area (FLA), specific flag leaf weight (SFLW), days to heading (DH), tillers per plant (TP), plant height (PH), peduncle length (PDL), spike length (SL), spikelets per spike (SS), grains per spike (GS), 1000-grain weight (GW), grain weight of mother shoot (GWMS), biomass per plant (BP), grain yield per plant (GY) and harvest index (HI) in a 6 x 6 diallel cross under drought stress conditions

	SF	LV	FLA	SFLW	DH	TP	PH	PDL	SL	SS	GS	GW	GWMS	BP	HI	r_g
SF	(-0.2005)	0.0968	0.1953	-0.0552	-0.0143	0.0222	0.2039	-0.0163	0.0489	0.0081	0.0024	0.0378	-0.4020	0.1276	-0.0277	0.027
LV	-0.034	(0.6243)	0.0064	-0.4228	0.0668	-0.0375	0.0995	0.0599	0.0851	0.0430	0.0577	-0.0479	-0.1642	0.3719	-0.2260	0.012
FLA	-0.0922	0.0094	(0.4245)	-0.2530	-0.019	0.2642	0.2425	-0.1242	0.0588	0.1340	0.0077	0.7022	-1.0846	0.3089	0.3958	0.375
SFLW	-0.0187	0.4445	0.1809	(-0.3938)	0.0544	0.0090	0.1124	0.0153	0.0711	-0.2869	-0.0874	0.0293	0.0037	-0.2953	0.7155	0.304
DH	0.0351	0.5119	-0.0989	-0.3961	(0.0815)	-0.0605	-0.0426	0.1237	-0.0629	-0.330	0.0295	-0.0685	0.3439	-0.0252	-0.2848	-0.244
TP	0.0239	0.1255	-0.6007	0.0285	0.0264	(-0.1857)	-0.3013	0.1936	-0.1653	-0.037	-0.0350	-0.0786	1.1686	0.1103	-0.3093	-0.037
PH	-0.1303	0.2073	0.3434	-0.2227	-0.0116	0.1876	(0.2998)	-0.0860	0.1986	-0.0389	0.0413	0.0883	-1.8495	0.8652	0.2712	0.888
PDL	-0.0174	-0.1998	0.2879	0.0487	-0.0539	0.1932	0.1928	(-0.1871)	0.1995	0.1579	0.0176	0.0936	1.0794	0.6808	0.2877	0.616
SL	-0.0355	0.1817	0.0853	-0.1443	-0.0175	0.1055	0.2036	-0.1276	(0.2925)	-0.094	0.0428	0.0603	-1.0342	0.9605	0.1081	0.591
SS	0.0042	0.6973	-0.1477	-0.4424	0.0698	-0.0179	0.0303	0.0767	0.0714	(-0.3851)	0.0527	-0.0355	-0.2156	0.5576	-0.1635	0.150
GS	-0.0384	0.480	0.0437	-0.2316	0.0320	0.0870	0.1652	-0.0438	0.1676	-0.0270	(0.075)	0.004	-0.7601	0.5610	0.0165	0.311
GW	-0.0702	-0.2766	0.4012	-0.0202	-0.0517	0.1357	0.2449	-0.1620	0.1632	0.1263	-0.0078	(0.1081)	-1.0122	0.7486	0.2696	0.602
GWMS	-0.0624	0.0793	0.3562	-0.1585	-0.0127	0.1688	0.2980	-0.1562	0.2340	-0.0643	0.0441	0.0846	(1.2927)	0.9266	0.2222	0.658
BP	-0.0162	0.1473	0.0832	-0.2696	0.0013	-0.0131	0.1646	-0.0808	0.1781	-0.1348	0.0267	0.0513	-0.7601	(1.5759)	0.0188	0.970
HI	0.0174	-0.4431	0.5285	0.1633	-0.073	0.1817	0.2537	-0.1693	0.1018	0.1933	0.0039	0.0617	-0.9036	0.0930	(0.3179)	0.363

and significantly associated with flag leaf area, plant height and 1000-grain weight, while negatively and significantly with days to heading. Leaf venation was also significantly and positively correlated with specific flag leaf area, days heading, plant height, spike length, grains per spike and biomass per plant. A positive and significant interrelationship was observed between flag leaf area and specific flag leaf area, plant height, peduncle length, spike length, 1000-grain weight, grain weight of mother shoot, harvest index and grain yield per plant (Sheoran *et al.,* 1986; Srivastava *et al.,* 1988). Significantly negative correlation between flag leaf area and days to heading, tillers per plant and spikelets per plant. Specific flag leaf weight had positive and significant correlation with days to heading, plant height, spike length, spikelets per plant, grains per spike, grain weight of mother shoot, biomass per plant and grain yield per plant while negative with harvest index. A positive and significant association was observed between days to heading and tillers plant, spikelets per spike and grains per spike and negative with peduncle length, spike length, 1000-grain weight, grain weight of mother shoot, harvest index and grain yield peer plant.

In case of tillers per plant negative and significant interrelationship was recorded with plant height, peduncle length, spike length, grains per spike, 1000-grain weight, grain weight of mother shoot (Krotova, 1988) and harvest index (Srivastava *et al.,* 1988). Under drought stress conditions plant height, peduncle length and spike length were positively and significantly correlated grains per spike, 1000-grain weight, grain weight of mother shoot (Bessonova, 1988), biomass per plant, harvest index and grain yield plant. Similarly, a positive and significant correlation between grain yield and spike length was observed by Sheoren *et al.,* 1986; Bangarwa *et al.,* 1987 and Srivastava *et al.,* 1988. Spikelets per spike was positively and significantly associated with grains per spike, grain weight of mother shoot and biomass per while negatively with 1000-grain weight and harvest index Significant and positive correlation was noted between grains per spike and grain weight of mother shoot, biomass per plant and grain yield per plant (Sheoran *et al.,* 1986; Wang *et al.,* 1991). 1000-grain weight was positively and significantly associated with grain weight of mother shoot, biomass per plant, harvest index and grain yield per plant (Wang *et al.,* 1991). Grain weight of mother shoot was also positively and significantly correlated with biomass per plant, harvest index and grain yield per plant (Atale and Zope, 1988; Wang *et al.,* 1991). Significant and positive correlation occurred for biomass per plant and harvest index (Srivastava *et al.,* 1988) with grain yield per plant (Bangarwa *et al.,* 1987; Atale and Zope, 1988; Srivastava *et al.,* 1988; Singh *et al.,* 1990).

Path-coefficient analysis: Direct and indirect effects under drought stress conditions are given in Table 3. Stomatal frequency had negative direct effect on grain yield, whereas positive indirect effects were noted viaflag leaf area, plant height and biomass per plant. Leaf venation had the positive direct effect on grain yield and positive indirect effect through biomass per plant followed by plant height and spike length. In case of flag leaf area positive direct effect was observed on grain yield. Whereas maximum indirect effect was exhibited via 1000-grain weight and followed by harvest index and biomass per plant. Specific flag leaf weight had negative direct effect on grain yield which was compensated by the positive indirect effect through harvest index, leaf venation, flag leaf area and plant height. Days to heading had positive direct effect and positive indirect effects on grain yield via leaf venation, grain weight of mother shoot and peduncle length. Tillers per plant had negative direct effect, while maximum and positive indirect effects on grain yield was observed via grain weight of mother shoot.

Under drought stress conditions plant height has also the positive direct effect and indirect effect was observed via biomass per plant followed by flag leaf area and leaf venation. Peduncle length had negative direct effect on grain yield and maximum positive indirect effect was noted via grain weight of mother shoot followed by biomass per plant. Positive direct effect was observed by SL on grain yield (Bangarwa *et al.,* 1987; Ahmad *et al.,* 1994) while maximum indirect effect through biomass per plant. The direct effect of spikelets per spike on grain yield was negative and maximum positive indirect effect was found through leaf venation and followed by biomass per plant. Grains per spike had positive direct effect on grain yield (Dornescu, 1986; Sheoran *et al.,* 1986; Bangarwa *et al.,* 1987; Wang *et al.,* 1991; Ahmad *et al.,* 1994) and positive indirect effects via biomass per plant, leaf venation, spike length and plant height. Positive direct effect was observed by 1000-grain weight on grain yield (Dornescu, 1986; Sheoran *et al.,* 1986) and positive indirect effect through biomass per plant, flag leaf area and harvest index. Grain weight of mother shoot showed negative direct effect on grain yield, however, compensated through the indirect effects of biomass per plant, flag leaf area and plant height. Biomass per plant exhibited maximum positive direct effect on grain yield (Bangarwa *et al.,* 1987; Singh *et al.,* 1990; Sharma and Singh, 1991) and indirect effect via spike length under drought stress conditions (Bangarwa *et al.,* 1987). Harvest index has positive direct effect on grain yield (Dornescu, 1986; Wang *et al.,* 1991) and positive indirect effects through flag leaf area.

The more detailed analysis of relationships provided by path-coefficient analysis shows that grain yield arid yield components are interrelated in a complex and dynamic manner.

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