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Character Association and Path Analysis in Water Stress Tolerant Accessions of Maize (*Zea mays* L.)

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An experiment was conducted to study the correlation and path analysis for eleven characters of maize. Material was evaluated under well watered and moisture deficit conditions. The hybrids exhibited significant differences in grain yield and other traits under both moisture deficit and well-watered conditions. In both the conditions, grain yield showed significant and positive correlation with cob weight. In case of moisture deficit condition, grain yield was negatively correlated with days to maturity which indicates that early maturing hybrids are advantageous. Number of cobs/plant exhibited negative relationship with cob weight in moisture deficit and well watered condition. Path coefficient analysis revealed that cob weight and cob length had high positive indirect effect with grain yield in both conditions. Direct negative effects on grain yield were attributed due to days to 50% silking, cob girth and shank weight which indicates that selections for longer interval of anthesis and silking result in less grain yield. Drought stress alone can account for a significant percentage of average yield losses. Yet, despite variable environments, commercially available new maize hybrids continue to be produced each year with ever-increasing harvestable yield.

Key words: Maize, water stress, correlation, path analysis.

Among various abiotic stresses, water is one of major environmental constraints that limit crop productivity world wide (Arans *et al.*, 2002). Significant yield loss in maize from drought is expected to increase with global climate change as temperature rise and rainfall distribution changes in key traditional production areas. Drought stress alone can account for a significant percentage of average yield losses. Screening and selection of plants of different crops with considerable water stress tolerance has been considered an economic and efficient means of utilizing drought – prone areas when combined with appropriate management practices to reduce water loss (Rehman et al., 2005). Over the years, maize breeders have aimed to generate hybrids with higher grain yield potential, better grain yield stability and improved grain traits for end-users (Duvick, 1997). The development of maize hybrids may allow further expansion of maize production into large unexploited areas with short growing season. Manivannan (1998) studied the character association in maize and reported that ear diameter, kernel rows, 1000 grain weight, kernels per row and ear length had positive significant correlation with seed yield. Gautam *et al*., (1999) reported that grain yield had maximum correlation with number of kernels per row followed by plant height. The objective of this experiment was to evaluate the genotypic and phenotypic correlations and direct and indirect effect of different quantitative traits on grain yield in maize hybrids under well watered and moisture deficit condition.

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Materials and Methods

The field experiment was carried out at Seed Research and Technology Centre, Rajendranagar, Hyderabad during *Rabi* 2009-10 with 15 maize hybrids in a Randomized Block Design with three replications. Two seeds of each entry were planted in each of 25 hills 20 cm apart in six row plots keeping 60 cm row-to-row distance. After emergence, each hill was thinned to single plant. The trials were planted in two adjacent blocks in the same field that received different irrigation treatments. The blocks were separated by planting 4 m wide commercial hybrid between blocks to minimize lateral movement of water from the well watered to the drought stress block. One of the block, hereafter referred to as well-watered condition, continued to receive irrigation water every week until the hybrids attained physiological maturity. In the second block, moisture deficit (drought stress) was imposed by the crop was allowed to mature with only two irrigations after anthesis.

The data was recorded on randomly 20 plants in each replication for characters *viz.*, days to 50% tasselling, days to 50% silking, days to maturity, plant height (cm), cob height (cm), cob length (cm), cob girth (cm), No. of cobs/plant, cob weight (kgs), shank

weight (kgs) and grain yield/plant. The data was statistically analyzed to estimate correlation coefficients and path coefficients following the method of Dewey and Lu (1959).

Results and Discussion

The data presented in Table-1 revealed that genotypic correlations were slightly higher in magnitude than phenotypes under moisture deficit

Table 1. Phenotypic (P) and Genotypic (G) correlation coefficient analysis of yield and yield contributing characters in maize under moisture deficit condition

Characters		Days to 50% tasseling	Days to 50% silking	Days to Maturity	Plant height (cm)	Cob height (cm)	Cob length (cm)	Cob girth (cm)	No. of cobs/ plant	Cob weight (kg)	Shank weight (kg)	Grain yield (kg)
Days to 50% tasseling	P	1.000	0.722**	0.291	0.03	0.045	-0.136	0.201	-0.011	0.177	0.268	0.310**
	G	1.000	0.003	0.373**	0.004	0.04	-0.154	0.306**	-0.136	0.206	0.305**	0.325**
Days to 50% silking	P		1.000	0.175	-0.031	-0.112	-0.164	0.241	-0.18	0.175	0.121	0.251
	G		1.000	0.279	-0.026	-0.156	-0.184	0.245	-0.215	0.214	0.123	0.269
Days to Maturity	P			1.000	-0.13	0.281	-0.222	-0.15	0.176	-0.215	-0.383**	-0.15
	G			1.000	-0.149	0.329**	-0.261	-0.029	0.193	-0.245	-0.423**	-0.218
Plant height (cm)	P				1.000	-0.038	0.306**	0.268	0.174	0.643**	0.308**	0.667**
	G				1.000	-0.04	0.314**	0.276	0.176	0.660**	0.455**	0.694**
Cob height (cm)	P					1.000	0.325**	0.404**	0.277	-0.215	-0.223	0.298**
	G					1.000	0.339**	0.425**	0.298**	-0.219	-0.408*	0.310**
Cob length (cm)	P						1.000	0.652**	0.186	0.106	0.09	0.099
	G						1.000	0.700**	0.19	0.11	0.159	0.12
Cob girth (cm)	P							1.000	-0.154	0.318**	0.138	0.299**
	G							1.000	-0.176	0.340**	0.204	0.336**
No. of cobs/plant	P								1.000	-0.379**	-0.167	0.381**
	G								1.000	-0.387**	-0.252	0.394**
Cob weight (kgs)	P									1.000	0.496**	0.879**
	G									1.000	0.741**	0.894**
Shank weight (kgs)	P										1.000	0.337**
	G										1.000	0.663**

*Significant at 5 per cent level ** Significant at 1 per cent level

P represents Phenotypic correlation coefficient G represents Genotypic correlation coefficient

group. This indicates that though there was a strong inherent association between characters studied, its expression was lessened due to the influence of environment. But, there was a general agreement in both sign and magnitude between the estimates of genotypic and phenotypic correlations. Grain yield per plant had positive significant relationship with days to 50% tasselling, plant height, cob girth, cob weight, No. of cobs / plant and shank weight. Grain yield exhibited highest positive correlation with cob weight per plant followed by plant height, days to 50% tasselling and cob girth. Cob weight showed

Table 2. Phenotypic (P) and Genotypic (G) correlation coefficient analysis of yield and yield contributing characters in maize under well watered condition

Characters		Days to 50% tasseling	Days to 50% silking	Days to Maturity	Plant height (cm)	Cob height (cm)	Cob length (cm)	Cob girth (cm)	No. of cobs/ plant	Cob weight (kg)	Shank weight (kg)	Grain yield (kg)
Days to 50% tasseling	P	1.000	0.733**	0.299**	0.218	0.073	-0.074	0.288	-0.301**	0.057	0.064	0.420**
	G	1.000	0.740**	0.357**	0.263	0.090	-0.095	0.307**	-0.351**	0.070	0.122	0.432**
Days to 50% silking	P		1.000	0.171	0.232	-0.051	-0.075	0.194	-0.299**	0.030	0.050	0.299**
	G		1.000	0.305**	0.328**	-0.081	-0.100	0.255	-0.331**	0.050	0.125	0.299**
Days to Maturity	P			1.000	-0.463**	0.294**	-0.150	-0.036	0.510**	0.401**	-0.369**	0.462**
	G			1.000	-0.540**	0.424**	-0.151	-0.082	0.515**	0.458**	-0.499**	0.530**
Plant height (cm)	P				1.000	-0.449**	0.202	0.103	-0.288	-0.009	0.549**	-0.119
	G				1.000	-0.490**	0.206	0.114	-0.300**	-0.013	0.645**	-0.124
Cob height (cm)	P					1.000	0.406**	0.307**	0.256	0.045	-0.052	0.520**
	G					1.000	0.412**	0.370**	0.264	0.043	-0.096	0.530**
Cob length (cm)	P						1.000	0.081	0.306**	0.225	0.181	0.386**
	G						1.000	0.085	0.318**	0.230	0.216	0.389**
Cob girth (cm)	P							1.000	-0.186	0.055	0.155	0.017
	G							1.000	-0.223	0.057	0.177	0.019
No. of cobs/plant	P								1.000	-0.082	-0.442**	0.013
	G								1.000	-0.096	-0.558**	0.078
Cob weight(kg)	P									1.000	-0.030	0.978**
	G									1.000	-0.115	0.984**
Shank weight (kg)	P										1.000	-0.294**
	G										1.000	-0.298**

*Significant at 5 per cent level ** Significant at 1 per cent level

P represents Phenotypic correlation coefficient G represents Genotypic correlation coefficient

significant positive correlation with cob girth and shank weight. Days to maturity is negatively correlated with grain yield in moisture deficit condition. No. of cobs / plant had negative significant relation with cob weight. In well watered condition, grain yield had significant and positive relationship with most of the traits except plant height, cob girth and No. of cobs / plant and shank weight (Table-2). Grain yield has highest positive correlation with cob weight followed by cob height and days to maturity.

Table 3. Phenotypic (P) and Genotypic (G) path coefficient analysis of yield and yield contributing characters in maize under moisture deficit condition

Characters		Days to 50% tasseling	Days to 50% silking	Days to Maturity	Plant height (cm)	Cob height (cm)	Cob length (cm)	Cob girth (cm)	No. of cobs/ plant	Cob weight (kg)	Shank weight (kg)	Grain yield (kg)
Days to 50% tasseling	P	0.160	0.011	0.042	0.047	0.017	-0.002	0.024	-0.008	0.019	0.024	-0.335**
	G	0.257	0.025	0.101	0.075	0.061	-0.017	0.052	-0.012	0.045	0.042	-0.342**
Days to 50% silking	P	-0.002	-0.073	-0.060	0.015	0.034	0.060	-0.009	0.049	-0.006	-0.005	-0.315**
	G	-0.011	-0.111	-0.111	0.045	0.072	0.090	-0.023	0.105	-0.012	-0.015	-0.361**
Days to Maturity	P	0.010	0.016	0.351	0.029	0.049	-0.007	-0.006	0.016	-0.075	-0.013	-0.150
	G	0.014	0.051	0.373	-0.045	0.101	-0.010	-0.012	0.052	-0.098	-0.045	-0.245
Plant height (cm)	P	0.003	-0.031	-0.005	0.415	-0.024	0.012	0.012	0.037	0.026	0.012	0.667**
	G	0.021	-0.081	-0.012	0.304	-0.071	0.080	0.072	0.062	0.082	0.081	0.687**
Cob height (cm)	P	-0.001	0.054	-0.010	0.015	-0.354	-0.006	-0.014	-0.009	0.077	0.108	-0.213
	G	-0.006	0.102	-0.016	0.002	-0.474	-0.015	-0.025	-0.024	0.111	0.011	-0.284
Cob length (cm)	P	-0.006	-0.027	-0.010	0.013	0.015	0.471	0.032	0.008	0.025	0.064	0.099
	G	-0.008	-0.059	-0.018	0.005	0.010	0.527	0.121	0.025	0.061	0.032	0.140
Cob girth (cm)	P	-0.008	-0.038	0.045	-0.003	-0.013	0.015	-0.331	0.015	-0.010	-0.084	0.299**
	G	-0.028	-0.079	0.092	-0.008	-0.025	0.112	-0.359	0.061	-0.015	-0.062	0.314**
No. of cobs/plant	P	-0.001	-0.042	0.102	0.224	0.013	-0.136	-0.009	0.120	-0.048	-0.002	-0.381**
	G	-0.009	-0.079	0.251	0.307	0.081	-0.145	-0.021	0.415	-0.098	-0.045	-0.395**
Cob weight(kg)	P	0.184	0.182	-0.022	0.044	-0.224	0.043	0.331	-0.395	0.423	0.517	0.791**
	G	0.190	0.215	-0.032	0.085	-0.231	0.101	0.401	-0.405	0.521	0.780	0.810**
Shank weight (kg)	P	-0.052	-0.024	0.075	0.011	0.044	-0.224	-0.027	0.033	-0.097	-0.396	0.337**
	G	-0.062	-0.035	0.265	0.076	0.029	-0.332	-0.051	0.085	-0.125	-0.410	0.354**

Phenotypic residual effect = 0.0833 Genotypic residual effect = 0.3853

P represents Phenotypic correlation coefficient **G** represents Genotypic correlation coefficient **Bold** values are direct effects

Path coefficient analysis allows separating direct effect and their indirect effects through other attributes by partitioning correlation (Wright, 1921). Path coefficient analysis revealed that characters *viz*., cob length, cob weight, plant height, No. of cobs/ plant and days to maturity had high positive direct effects towards grain yield in moisture deficit condition (Table-3). Cob length exhibited the highest direct effect on grain yield followed by cob weight and number of cobs per plant. In general, character exhibiting high direct effects for grain yield also exhibited high degree of positive correlation with

Table 4. Phenotypic (P) and Genotypic (G) path coefficient analysis of yield and yield contributing characters in maize under well watered condition

Characters		Days to 50% tasseling	Days to 50% silking	Days to Maturity	Plant height (cm)	Cob height (cm)	Cob length (cm)	Cob girth (cm)	No. of cobs/ plant	Cob weight (kg)	Shank weight (kg)	Grain yield (kg)
Days to 50% tasseling	P	-0.004	-0.003	-0.001	-0.009	-0.003	0.003	-0.001	0.002	-0.002	-0.003	-0.420**
	G	-0.014	-0.014	-0.051	-0.003	-0.002	0.001	-0.004	0.005	-0.001	-0.007	-0.509**
Days to 50% silking	P	0.006	-0.009	0.002	0.002	-0.005	-0.007	0.002	-0.003	0.003	0.005	-0.294**
	G	0.019	-0.018	0.055	0.006	-0.001	-0.002	0.005	-0.006	0.009	0.003	-0.321**
Days to Maturity	P	-0.004	-0.001	-0.008	0.003	0.002	0.001	0.003	-0.004	-0.003	0.003	-0.462**
	G	0.003	0.002	0.008	-0.004	0.004	-0.001	-0.007	0.005	0.004	-0.004	-0.530**
Plant height (cm)	P	-0.002	-0.005	0.009	-0.002	0.009	-0.004	-0.002	0.006	0.000	-0.001	-0.119
	G	0.005	0.06	-0.009	0.017	-0.009	0.004	0.002	-0.005	-0.002	0.011	-0.124
Cob height (cm)	P	-0.004	0.001	-0.004	0.007	-0.016	-0.006	-0.005	-0.004	0.000	0.001	-0.622**
	G	0.001	-0.001	0.006	-0.007	0.002	0.006	0.005	0.004	0.001	-0.001	0.642**
Cob length (cm)	P	-0.001	-0.002	-0.004	0.006	0.001	0.003	0.002	0.009	-0.001	0.005	0.186
	G	-0.002	-0.002	-0.003	0.004	0.008	0.023	0.003	0.006	0.005	0.008	0.189
Cob girth (cm)	P	-0.002	-0.001	0.003	-0.008	-0.02	-0.006	-0.007	0.002	0.007	-0.001	0.017
	G	-0.004	-0.003	0.001	-0.002	-0.005	-0.001	-0.012	0.003	-0.007	-0.002	0.019
No. of cobs/plant	P	-0.002	0.004	-0.001	0.004	-0.003	0.004	0.003	-0.002	0.001	0.006	0.135
	G	0.008	0.007	-0.001	0.007	-0.006	-0.007	0.005	-0.032	0.002	0.002	0.148
Cob weight(kg)	P	0.004	0.029	0.393	-0.009	0.044	0.22	0.054	-0.08	0.979	-0.03	0.978**
	G	0.006	0.047	0.431	-0.012	0.04	0.217	0.054	-0.09	0.947	-0.108	0.984**
Shank weight (kg)	P	0.056	-0.01	0.074	-0.111	0.01	-0.036	-0.314	0.089	0.006	-0.202	-0.234
	G	-0.026	-0.054	0.108	-0.14	0.021	-0.046	-0.038	0.121	0.025	-0.218	-0.293**

Phenotypic residual effect=0.0186 Genotypic residual effect=0.3302 **P** represents Phenotypic correlation coefficient

G represents Genotypic correlation coefficient **Bold** values are direct effects

grain yield. Cob weight had high positive indirect effect through cob length, shank weight, plant height, cob girth, days to 50% flowering and days to 50% silking and days to maturity.

Under well watered condition, cob weight, cob length and days to 50% silking exhibited positive direct effect with grain yield (Table 4). Cob weight exhibited highest positive direct effect with grain yield. Cob weight had high positive indirect effect through days to maturity, cob length and cob girth. Cob length had positive indirect effect through plant height, cob height, cob girth and shank weight. Direct negative effects on grain yield were attributed by days to 50% tasselling, days to 50% silking, cob height, cob girth and shank weight which indicates that selections for longer interval of anthesis and silking result in less grain yield. This was in concurrence with the earlier reports of Mohan *et al*., (2002), Singh *et al*., (2003) and Sofi and Rather (2007).

It was concluded that in moisture stress and well watered conditions grain yield showed significant and positive correlation with cob weight. In case of moisture deficit condition grain yield was negatively correlated with days to maturity which indicates that early maturing hybrids are advantageous. Path coefficient analysis revealed that cob weight and cob length had high positive indirect effect with grain yield in both conditions. Grain yield under moisture stress condition is less than the well watered condition due to less cob weight.

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