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Full Length Research Paper

A study of morphological basis of corn (*Zea mays* L.) yield under drought stress condition using correlation and path coefficient analysis

Maryam Ashofteh Beiragi[1], Mohsen Ebrahimi[2], Khodadad Mostafavi [3]*, Mohammad Golbashy[4], Saied Khavari Khorasani[5]

[1]Department of Agronomy and Plant Breeding, College of Agriculture, Zabol University, Zabol, Iran.
[2]Department of Agronomy & Plant Breeding- College of Abouraihan - University of Tehran, Iran.
[3]Islamic Azad University- Karaj Branch Iran.
[4]NanoBioTechnology- University of Tehran Iran.
[5]Scientific membrane of khorasan Razavi Agricultural Research and Natural Resources Center Mashhad, Iran.

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In order to study the morphological basis of corn yield under normal irrigation and drought stress condition, an experiment was carried out on basis of complete randomized block design with three replications and 28 new hybrids of corn; in addition 6 commercial hybrid (as control) under normal irrigation and drought stress condition in Khorasan Razavi Agricultural Research and Natural Resources Center, Mashhad, Iran on 2009. Genotypic and phenotypic correlation coefficients and path coefficients were estimated to determine the association and direct and indirect effects of different characters on total yield. Results of analysis of variance (ANOVA) showed that in both conditions there were significant differences between all hybrids for all traits. In normal irrigation condition KSC500 hybrid and in stress condition N-11 hybrid was better than others in grain yield trait. Under stress condition, number of kernels per row had the highest correlation with grain yield, while under normal irrigation ear diameter had the highest correlation with grain yield. According to this study, kernel No./ear is more closely and significantly related with total yield. This emphasized that selection based on the characters which enhance kernel number per ear will be more effective in improving yield under drought stress condition.

Key words: Corn hybrids, phenotypic correlation, genotypic correlation, drought stress, irrigation.

INTRODUCTION

Iran is very much less in yield due to drought stress at pollination stage, which leads to pollen desiccation and seed setting. Among various abiotic and biotic stress factors, drought stress is an important cause for genotype by environment interactions in maize across years, locations (Löffler et al., 2005) and most likely within individual fields (Bruce et al., 2002).

Drought is one of the most important abiotic stress factors (Bruce et al., 2002), which affects almost every aspects of plant growth (Aslam et al., 2006). Drought is a permanent constraint to agricultural production in many developing countries, and an occasional cause of losses of agricultural production in developed ones (Ceccarelli and Grando, 1996). The best option for crop production, yield improvement and yield stability under drought stress conditions is to develop drought tolerant crop varieties. One of the main goals in breeding programs is selection of the best genotypes under drought stress conditions (Richards et al., 2002). However, low heritability of drought tolerance and lack of effective selection approaches limit development of resistant crop cultivars to environmental stress (Kirigwi et al., 2004). Several reports of physiological, morphological and molecular traits have been suggested for improving the drought and salinity tolerance of crops that many of them potentially

*Corresponding author. E-mail: mostafavi@kiau.ac.ir. Tel: 00989365686610.

Table 1. Open pollinate population of maize used in this study and 6 hybrids from Iran.

Iranian hybrids	Open pollinate population	Open pollinate population	Open pollinate population
KSC704	Th 91A 1354-G 42 O NTR-2	Th 91A 1353-G 41 Q NTR-1	Th 92B 6270-10-POb-44G2
KDC370	Th 97B 6088-POb-91 CD	Th 88A 1344-S87 P 69Q	Th 89B 6324-Rio-Hater(1)-8561
KSC250	Th 94A 1126-Side-9245	Th 91A 1305 Comp-1-112	Th 93B 6020--Pob-47-cC5
KSC302	Th 94A 1128-Acress 9245	PR 91A 1306 Comp-1-54	PR 91B 5301 EDS 90620 Flint
KSC400	Th 87B 6089-Pob-92 C0	Th 94A 1122--E	PR 93B 5212-c peel.16 C21
KSC500	Th 94A 1128 Acress 9245	Th 93A 1121- Sakha-9134	Th 83A 1321 R-4-Acress -8569

Per ear will be more effective in improving yield.

applicable to maize. Several recent reviews are available (Barker et al., 2005; Flowers, 2004, Munns, 2002). No exact figures on yield and economic losses in maize due to drought are available. Heisey and Edmeades (1999) estimated that 20 to 25% of the global maize planting area is affected by drought in any given year. In maize, grain yield reduction caused by drought ranges from 10 to 76% depending on the severity and stage of occurrence (Bolaòos et al., 1993). Drought stress coinciding with flowering delays silking and results in an increase of anthesis-silking interval (Bolaòos et al., 1993); this usually associates with reduction in grain number and yield (Edmeades et al., 1993).

Correlation of particular character with other characters contributing to seed yield is of great importance for indirect selection of genotypes for higher seed yield. Path coefficient analysis helps partitioning the correlation coefficient into its direct and indirect effects. This experiment was conducted to estimate the genotypic and phenotypic correlations and direct and indirect contributions of different traits to seed yield under normal and water stress.

MATERIALS AND METHODS

The present study was conducted to evaluate the effects of drought stress on maize hybrids (34 hybrids) in yield and yield component and estimate the genotypic and phenotypic correlations and direct and indirect contributions of different traits to grain yield, in Khorasan Razavi Agricultural Research and Natural Resources Center, Mashhad, I.R. Iran during 2009. The hybrids consisted of 28 maize hybrids which were obtained from 18 famous open pollinate population and 6 Iranian hybrids of single cross groups (Table 1). Two independent experiments were laid out in randomized complete block design (RCBD) with three replications at both normal and drought stress conditions. The hybrids were grown in two row plots, with 3.15 m length and 0.75 cm between rows. The plant density was 75000 plant/ha. Fertilizer was used based on soil test. Irrigation was done based on 50 and 80% allowed water depletion for non-stress and stress conditions, respectively.

Data were recorded on 10 competitive plants of each plot and grain yield (kg ha^{-1}) was calculated for the entire plot. The data recorded were subjected to correlation analysis to estimate genotypic and phenotypic correlation coefficients between different traits following the method described by Kwon and Torrie (1964). Data were statistically analyzed using ANOVA appropriate for RCBD with SAS ver. 9.1 and Path coefficients were determined following Dewey and Lu (1957) using genotypic correlation with Path 2 software's. Means were compared using Duncan's multiple range test at 0.05 level of probability when the F values were significant (Steel and Torrie, 1984).

RESULTS

Results of ANOVA showed significant differences among hybrids in all of traits at both, normal irrigation and drought stress condition ($P \leq 0.01$) (Table 2), which demonstrates high diversity among combinations that enabled us to screen and select drought tolerant hybrids. Corn hybrids showed different sensitivity to drought. Among all hybrids, KSC500 (13.79 ton/ha) and KSC302 (12.89 ton/ha) had the highest and H11 (5.69 ton/ha) and KSC250 (4.51 ton/ha) produced the highest yields in optimal and stress conditions, respectively. The other researcher showed that drought stress declined grain yield and its component (Reca et al., 2001; Seghatoleslami et al., 2008).

In general, means comparisons of maize hybrids indicated that under water deficit condition the maximum ear weight, kernel no. per row, total kernel no. per ear and kernel percentage in ear was obtained in H11 hybrid (data not shown). Westgate and Boyer (1985) found that water stress during the critical period of silking to early grain filling inhibits photosynthesis and consequently lowers the carbohydrate reserves to levels that are insufficient to support optimum reproductive development. Such effects explain the observations made in this study concerning the reduction of kernel number in ear in the non-stress condition versus drought stress condition (Table 2). Other research shown that under water stress condition, a maize plant will be able to make a better use of available water if vegetative growth is restricted early in the season (Shekoofa and Emam, 2006).

Results of this experiment indicated that yield component such as ear no. per plant, 300- kernel weight, row no. per ear, kernel no. per row and ear length were affected by water deficit condition. The percent of total yield reduction in stress condition was 71.54% (Table 2). Water stress reduced both Plant height (-32.8%) and ear

Table 2. Analysis of variance of investigated traits in corn hybrids under both normal and drought stress condition.

	Normal condition					Stress condition					
	Replication	Genotype	Error	CV (%)	Mean	Replication	Genotype	Error	CV (%)	Mean	Variation percentage
Plant height (cm)	1140.37**	749.19**	140.02	5.08	232.73	4242.03**	479.05**	89.81	6.05	156.4	-32.80
Ear height (cm)	49.23ns	494.06**	58.4	7.21	105.97	1096.7**	231.9**	30.7	7.53	73.57	-30.57
Stem diameter (mm)	22.47**	9.98**	3.65	9.71	19.68	13.96*	11.31**	2.87	10.37	16.33	-17.02
leaves No.	7.04**	2.17**	0.18	3.35	12.94	5.45**	2.63**	0.17	3.22	13.11	1.31
upper leaves No.	0.05ns	0.52**	0.03	3.34	5.82	0.0003ns	0.35**	0.02	2.74	5.73	-1.55
Ear No. in plant	0.0004ns	0.04**	0.01	12.53	1.06	0.0006 ns	0.19**	0.02	12.43	1.34	26.42
10 ear weight (Kg)	1.55**	0.22**	0.03	7.54	2.61	0.03 ns	0.1**	0.01	13.86	0.84	-67.82
10 cob weight (Kg)	0.05**	0.03**	0.003	11.36	0.5	0.002 ns	0.01**	0.001	12.55	0.28	-44
300 kernel weight (gr)	364.28**	235.59**	69.07	9.9	83.93	175.47 *	155.45**	48.35	9.62	72.26	-13.9
Row No./ear	0.11ns	5.78**	0.55	4.54	16.38	5.46 **	4.76**	0.83	7.65	11.96	-26.98
kernel No./row	90.87**	20.09**	3.3	4.57	39.73	4.95 ns	33.88**	5.49	13.05	17.95	-54.82
total kernel No./ear	30842.82**	9396.63**	2072.36	7	649.77	5452.08 *	9965.13**	1694.37	18.77	219.24	-66.26
Ear length (cm)	14.87**	6.42**	0.6	4.66	16.68	3.81 *	6.92**	0.95	8.12	12.04	-27.82
ear diameter (mm)	32.46**	14.37**	1.68	2.64	49.1	9.66 ns	25.03**	9.28	8.1	37.59	-23.44
cob diameter (mm)	4.88*	9.33**	1.38	4.2	27.99	0.08 ns	16.43**	3.88	8.48	23.22	-17.04
kernel depth (mm)	3.04**	2.13**	0.51	6.78	10.55	0.99 ns	2.25**	0.39	8.64	7.25	-31.28
Total yield (ton/ha)	28.46**	7.12**	2.64	15.62	10.4	4.18 **	2.58**	0.38	20.98	2.96	-71.54

*, ** Significant at 0.05 and 0.01 probability levels, respectively.

height (-30.57%). Results of this experiment showed that drought stress affected total leaves number positively (Table 1), and this was associated with the reduction in mean plant height (-32.8%) and stem diameter (-17.02%).

Our results concur partly with observations made by Choukan *et al* (2007) who reported that the total yield decreased with increasing water deficit. The measurement of total yield components showed that in drought stress condition total yield decline was mainly due to reduction of kernel no. per row and total kernel no. per ear (Shoa Hoseini *et al* 2007). Grain weight reduction under drought stress condition might be a result of kernel depth reduction.

Combined statistical analysis of data revealed that irrigation condition and their interaction (condition by hybrids) had significant differences for all of measured traits (data not shown). Study of phenotypic correlation between studied variables and total yield in both conditions showed that all variables were positively correlated with total yield, except stem diameter (-0.02ns) and total leaves number (-0.04ns) under drought condition. In normal irrigation condition, the highest correlations were belonged to ear diameter and total yield (0.68**). The correlation between plant height and ear height in drought stress was 0.98; the best of all variables studied. This finding was in agreement with the results of Hoseini et al. (2007). Result of this study showed that, kernel no. per row could be used as an important trait for prediction of total yield under drought stress. This finding was in agreement with the results of Iafari et al. (2009) and Choucan et al. (2007).

The strongest correlation of total yield in drought stress condition was observed with kernel number per row at both genotypic (rg = 0.837) and phenotypic (rp = 0.798) levels (Table 3). Also in drought stress condition, total yield was positively and significantly correlated at genotypic level with kernel number per row (0.837), total kernel number per ear (0.779), ear length (0.615) and kernel percentage (0.624). The results are in accordance with the findings of Ali (1994) and Golbashy et al. (2009 b).

Negative but non-significant genotypic correlations of total yield in stress condition were observed with plant height, ear height and stem diameter and other measured traits were positive correlated with total yield. At phenotypic level, ear no./plant (0.399), 300 kernel weight (0.286) and row no./ear (0.511) exhibited positive but non-significant correlation with total yield. Total yield was positively and non-significantly correlated, at phenotypic level, with other measured traits than stem diameter and leaves number.

The highest correlation at genotypic level at drought stress condition was observed between kernel no. per row and total kernel no. per ear (rg = 0.95). The results are at par with the finding of Golbashy et al. (2009 a). Stem diameter exhibited negative correlation with total yield at both genotypic and phenotypic levels.

Path coefficients in drought stress condition (Table 4) revealed that kernel percentage per ear had maximum direct effect (0.4712) on total yield. Other researcher

Table 3. Phenotypic (r_P) and genotypic (r_G) correlation coefficients among different characters of maize under normal (on diameter) and drought stress (diameter under) condition.

	Traits		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Plant height	rP	1	0.623	0.221	-0.124	-0.132	0.421	-0.036	0.069	0.032	0.077	0.350	0.057	0.375
		rG		0.509*	0.141	0.040	-0.254	0.400	0.041	-0.310	-0.191	-0.130	0.290	-0.061	0.171
2	Ear height	rP	0.801**	1	0.254	0.251	-0.044	0.085	0.043	0.139	0.128	0.111	0.234	-0.095	0.299
		rG	0.745**		0.250	0.451	0.042	-0.091	0.093	-0.040	0.038	0.040	0.185	-0.234	0.278
3	Stem diameter	rP	0.224*	0.347**	1	0.191	0.176	0.106	0.201	0.060	0.237	0.300	0.086	-0.096	0.226
		rG	0.251	0.428		0.547*	0.237	0.138	0.200	-0.317	-0.021	0.367	-0.230	-0.350	0.043
4	Leaves No.	rP	0.033	0.359**	0.324**	1	0.028	-0.297	0.257	-0.125	0.115	0.062	-0.083	-0.165	0.050
		rG	0.466	0.742**	0.518*		-0.033	-0.222	0.330	0.049	0.378	0.214	0.113	-0.083	0.343
5	Ear No./plant	rP	0.083	-0.050	-0.053	0.063	1	-0.051	0.185	-0.018	0.148	-0.163	0.135	0.051	0.431
		rG	0.190	0.017	0.066	0.126		-0.512*	0.360	-0.108	0.286	-0.512*	0.207	0.144	0.236
6	300 kernel weight	rP	0.249*	0.135	0.135	-0.084	-0.105	1	-0.485	0.249	-0.217	0.318	0.181	-0.062	0.175
		rG	0.074	0.003	0.222	0.115	-0.082		-0.634**	0.193	-0.503	0.345	0.012	-0.036	-0.033
7	Row No./ear	rP	-0.096	-0.096	-0.140	-0.107	-0.094	-0.065	1	-0.219	0.690	-0.344	0.222	0.055	0.199
		rG	-0.267	-0.165	-0.210	0.000	-0.217	-0.178		-0.425	0.741**	-0.510	0.340	0.047	0.445
8	Kernel No./row	rP	0.081	0.113	-0.028	0.040	0.124	0.111	0.690	1	0.552	0.638	0.271	0.243	0.396
		rG	-0.006	0.117	-0.025	0.196	0.198	0.057	0.631**		0.291	0.596**	0.094	0.224	0.354
9	Total kernel No./ear	rP	0.024	0.043	-0.052	-0.022	0.063	0.035	0.861**	0.956	1	0.181	0.381	0.220	0.462
		rG	-0.102	0.010	-0.072	0.132	0.065	-0.063	0.836**	0.950**		-0.095	0.441	0.214	0.732**
10	Ear length	rP	0.071	0.140	-0.019	0.270**	0.355**	0.099	0.190	0.634**	0.491	1	-0.135	-0.213	0.163
		rG	0.302	0.402	0.155	0.390	0.435	0.174	-0.003	0.642**	0.452		-0.449	-0.347	-0.102
11	Kernel depth	rP	-0.159	-0.216*	-0.086	-0.172	-0.188	0.195*	0.390**	0.254	0.323	0.055	1	0.609	0.613
		rG	-0.410	-0.434	-0.273	-0.201	-0.391	0.349	0.497	0.261	0.344	-0.013		0.608**	0.683**
12	Kernel percentage	rP	-0.137	-0.199*	-0.104	-0.219*	-0.056	0.192	0.646**	0.595	0.647	0.137	0.573	1	0.297
		rG	-0.467	-0.387	-0.311	-0.188	-0.030	0.172	0.645	0.595**	0.667**	0.024	0.738**		0.401
13	Total yield(ton/ha)	rP	0.192	0.111	-0.021	-0.042	0.399**	0.286**	0.511**	0.798	0.755	0.540	0.303	0.612	1
		rG	-0.125	-0.086	-0.062	0.188	0.481	0.224	0.473	0.837**	0.779**	0.615**	0.256	0.624**	

*, ** Significant at 0.05 and 0.01 probability levels, respectively.

Table 4. Direct (bold diagonal values) and indirect effects of different character on total yield in maize under normal irrigation condition. (Path analysis using genotypic correlation).

		Total value	1	2	3	4	5	6
1	Ear diameter	0.8369	0.8689	-0.0584	-0.0747	-0.0012	0.0108	0.0914
2	Ear No./plant	0.2363	0.3511	-0.1446	-0.0431	0.001	0.0534	0.0184
3	kernel No./row	0.3540	-0.1623	0.0156	0.3997	-0.0004	0.0832	0.0182
4	flag leaf height	0.4975	0.3122	0.0441	0.0496	-0.0033	0.0011	0.0938
5	cob percentage	-0.4011	-0.0253	0.0208	-0.0894	0.000009	-0.3719	0.0647
6	10 ear weight	0.5013	0.4079	-0.0137	0.0374	-0.0016	-0.1236	0.1947

Residual effects: 0.315.

reported the similar results in their findings (Golbashy et al., 2009; Hoseini et al., 2007). Maximum positive indirect effect on total yield was exhibited by total kernel No./ear through 10 ear weight (0.3968). Also maximum negative indirect effect was observed by 300 kernel weight through ear no. per plant (-0.0321). The indirect effect of 300 kernel weight and kernel percentage on total yield through all other characters under study is positive except ear no. per plant which is negative (Table 5). This emphasizes that selection on the base of kernel percentage and 10 ear weight will be more effective in improving total yield of maize under drought conditions.

DISCUSSION

Ear length showed positive and significant correlation with most of the traits under drought stress condition.

Table 5. Direct (bold diagonal values) and indirect effects of different character on total yield in maize under drought stress condition. (Path analysis using genotypic correlation)

		Total value	1	2	3	4	5	6
1	Total kernel No./ear	0.836	0.0674	0.0779	0.0007	0.2812	0.3968	0.0130
2	Ear No./plant	0.480	0.0134	0.3922	-0.0009	-0.0144	0.0816	0.0088
3	300 kernel weight	0.223	0.0038	-0.0321	0.0114	0.0811	0.1560	0.0035
4	Kernel percentage	0.624	0.0401	-0.0119	0.002	0.4712	0.1212	0.0005
5	10 ear weight	0.736	0.0569	0.0681	0.0038	0.1217	0.4704	0.0158
6	Ear length	0.614	0.0433	0.1705	0.002	0.0113	0.3676	0.0202

Residual effects: 0.315.

When the ear length is more, ultimately there will be more kernel no. per row, therefore the correlation between ear length and kernel no. per row is significant and positive. Ultimately as a result of more kernel no. per row, total kernel no. will be more, increasing the yield. This is exhibited by significant and positive correlation of total kernel no. with total yield at genotypic level. The significant and positive correlation of total yield with total kernel No./ear at genotypic level and positive correlation with ear length and kernel percentage at both genotypic and phenotypic level and their positive direct effects on total yield showed that kernel No./ear is more closely and significantly related with total yield. Ear length and kernel percentage also had positive direct effects on total yield.

Conclusion

In this experiment, drought stress had significant effects on maize hybrids yield and its components. KSC500 (13.8 ton/ha) and KSC250 (12.9 ton/ha) hybrids were the best genotypes under normal condition and H11 (5.7 ton/ha) and KSC250 (4.51 ton/ha) showed the best behaviour under drought stress condition. Finally it is concluded that total yield mainly depends upon the kernel no. per ear. This emphasized that selection based on the characters which enhance kernel number

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