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An Evaluation of Quantitative Traits Related to Drought Resistance in Inbred Lines of Maize in Stress and Non-Stress Conditions

[1]Amir Ali Khalatbari, [1]Mohammad Reza Bihamta and [2]Amir Mahdi Khalatbari
[1]Department of Agronomy and Plant Breeding, Agriculture University of Tehran, Iran
[2]Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Tehran, Iran

Abstract: The objective of present study to evaluate the performance and resistance of a group of inbred lines selected under managed drought stress; to determine proper indices, those criteria with high correlation to yield and to apply practical analyses for superior genotypes based on the traits. In this research 30 inbred lines of corn were evaluated in field. Significant differences were observed among the Inbred lines for most traits in either stress or non-stress conditions. Most traits were negatively affected by drought stress, the highest reduction being observed in grain yield. The results of stepwise regression analysis showed that traits such as days to tassel initiation and days to pollination in non-stress condition could be used as desirable criteria for yield improvement. Under drought stress, traits such as number of ear per plant, number of rows per ear and number of seeds per row could be desirable criteria for yield improvement. Among the drought resistance indices, Mean Productivity (MP), Geometric Mean Productivity (GMP) and Stress Tolerance Index (STI) were the most suitable ones for drought resistance selection.

Key words: Drought stress, genetic diversity, inbred lines, drought resistance, corn

INTRODUCTION

Drought, like many other environmental stresses, has adverse effects on crop yield in Iran (Norouzi, 2001). Low water availability is one of the major causes for crop yield reductions affecting the majority of the farmed regions around the world. As water resources for agronomic uses become more limiting, the development of drought-resistant lines becomes increasingly more important. Evidence of variations for available lines within a field imply a need for a reasonable level of drought resistance in all maize inbred as parental lines for hybrids since farmers typically grow only one hybrid in any given field.

Drought is thought to cause average annual yield losses in maize of about 17% per year in the world (Edmeads *et al*., 1992), but losses in individual seasons have approached 60% in regions such as Southern Africa. Over the years, maize breeders have aimed to generate inbred with higher grain yield potential, better grain yield stability and improved grain traits for end-users.

Periods of soil water deficit can occur at any time during the crop season, but maize is particularly sensitive to water stress in the period 1 week before to 2 week after flowering (Denmand and Shaw, 1962). Drought at flowering commonly results in barrenness. One of the main causes of this, though not the only one (Heisey and Edmeads, 1998), is thought to be a reduction in the flux of assimilate to the developing ear below some threshold lever necessary to sustain grain formation and growth.

Drought which coincides with this growth period can cause serious yield instability at the farm level, it allows no opportunities for farmers to replant or otherwise compensate for loss of yield (Hekmat *et al*., 1993).

Evaluation of genetic variance components for traits is one of the fundamental activities in any breeding program (Sharma *et al*., 1998). To choose superior plants for high grain yield, different indices are applied (Fernandez, 1992). Grain yield is a complex trait and is dependent on many factors including vigorous growth, adequate water, nutrient supplies and improved genetics (Rosielle and Hamblin, 1982).

The objective of present study was to evaluate following conditions (i) the performance and resistance of a group of inbred lines selected under managed drought stress (ii) to determine proper indices, those criteria with high correlation to yield such as MP, GMP and STI (iii) to apply practical analyses for superior genotypes based on the traits.

MATERIALS AND METHODS

Thirty inbred lines were used in a study. These lines were developed according to different selection criteria.

Corresponding Author: Amir Ali Khalatbari, Department of Agronomy and Plant Breeding, Agriculture University of Tehran, Iran

A selection index for standardized variables across environments was used to select that best lines across water regimes.

Lines were evaluated separately in three trials planted side by side. Experimental designs were RCBD, Randomized Complete Block Design. Lines were over sown with two seeds per hill every 20 cm in single rows of 2.5 or 5 m in length spaced 75 cm apart, which were later thinned to the desired plant densities. All trials conducted at Seed and Plant Breeding and Propagation Institute, Karaj during the summer and autumn seasons. The location is largely rain free during these seasons, allowing the control of drought stress intensity by withdrawing or delaying irrigation for varying lengths of time during flowering and grain filling stages. Intermediate drought stress was achieved by withholding water from 2 week before silking to the end of the flowering period. Severe drought stress was achieved by withholding water from 4 to 5 week before silking to the end of flowering period.

Totals of 150 to 200 kg N ha^{-1}, 25 to 35 kg P ha^{-1} and no K were applied to all trials, with half the N and all of the P incorporated before planting and the remaining N being side dressed at about 30 day after sowing. Weeds, insects and disease were controlled where necessary by chemical means.

Traits are as follows: 1000 kernel weight, grain yield, wood percentage, humidity percentage, grain number per ear, number of harvestable plant, leaf width, leaf length, ear length, physiological maturity, days to pollination, days to tassel initiation. Data from mean of per plant were used to evaluate variance analysis, correlation coefficient, step wise regression and path analysis. The mean of each trait was estimated from 10 competitive plants which were chosen randomly. Each trait was estimated in comparison with other traits by the mean of stepwise regression analysis and those which were found in the equation, with principle components were applied to estimate direct and indirect effects of yield components by the mean of path analysis.

Individual analyses of variance were conducted for each trial. Statistical evaluations for simple variance and covariance analysis are estimated by MSTATC, step wise regression and principle components by SPSS, plotting biplot by STATGRAPH and path analysis by PATH 2.EXE.

RESULTS AND DISCUSSION

Results of variance analysis in three conditions are significantly different among following genotypes, based on the traits which are already discussed. Significant difference among genotypes indicates diversity although the selection is based on superior lines where the population could provide the diversity which is indispensable for breeding selection.

The consequences of traits correlation noted that generally all yield components including number of ear per plant, number of rows per ear and number of seeds per row have positive and significant correlation with all traits. In non-stress condition those traits such as tassel initiation, plant length, and wood percentage are correlated with yield significantly. In vegetative stress condition row number per ear, plant length, tassel initiation and pollination initiation are correlated with yield as well. Eventually in generative stress condition grain number per ear, number of harvestable plant and row number per ear are have significant correlation with yield, respectively.

To determine these relations in non-stress condition and the effect of traits chosen by step wise regression for grain yield, path analysis based on genotypic correlation has been applied.

According to results followed by path analysis (Table 1-3) it is concluded that in non-stress condition, direct effect of days to tassel initiation is bigger than other traits which are included in the equation (0.66). Indirect effect of this trait by plant length is negative (-0.013). Although direct effect of branch number on grain yield is 0.21 and its indirect effect by other traits are positive. In vegetative stress condition among all components with positive direct effect, days to tassel initiation have the largest impact (0.57). Direct effect of days to pollination initiation and grain number per ear are 0.34 and 0.041, respectively. In generative stress, direct effect of row number per ear on grain yield is 0.147 and the indirect effect by grain number per ear and number of harvestable plant are 0.005 and 0.011, respectively. Indirect effect of grain number per ear and row number of grain per ear are not considerable, but the direct effect of these traits on grain yield is significant.

Table 1: Path analysis of grain yield in non-stress condition based on genotype correlation in inbred lines of maize

		Indirect effect				
Traits	Direct effect	Days to tassel initiation	Plant height	Wood (%)	Branch No. per ear	Total correlation with yield
Days to tassel initiation	0.660	-	-0.013	0.109	0.030	0.763
Plant height	-0.133	0.006	-	0.144	0.070	0.087
Wood percentage	0.438	0.016	-0.044	-	0.011	0.421
Branch number per ear	0.210	0.015	0.003	0.014	-	0.332

Table 2: Path analysis of grain yield in vegetative-stress condition based on genotype correlation in inbred lines of maize

		Indirect effect				
Traits	Direct effect	Row No. per ear	Plant height	Days to tassel initiation	Days to pollination initiation	Total correlation with yield
Row number per ear	0.041	-	-0.019	-0.014	0.020	0.009
Plant height	-0.186	0.004	-	0.046	0.034	-0.102
Days to tassel initiation	0.570	-0.001	-0.016	-	0.023	0.575
Days to pollination initiation	0.340	-0.040	0.003	0.017	-	0.320

Table 3: Path analysis of grain yield in generative-stress condition based on genotype correlation in inbred lines of maize

		Indirect effect			
Traits	Direct effect	Grain No. per row	No. of harvestable plant	Grain No. per ear	Total correlation with yield
Grain number per row	0.122	-	0.002	0.005	0.129
Number of harvestable plant	0.020	0.023	-	0.003	0.046
Grain number per ear	0.147	0.005	0.011	-	0.163

Table 4: Correlation coefficient of drought resistant indices in vegetative stress

Parameters	YP	YS	MP	GMP	STI	SSI	TOL
YP	1	0.635••	0.744••	0.857••	0.822••	0.166	0.676••
YS		1	0.864••	0.941••	0.940••	-0.614••	-0.139
MP			1	0.887••	0.874••	-0.275	0.145
GMP				1	0.985••	-0.336	0.202
STI					1	-0.372•	0.157
SSI						1	0.797••
TOL							1

••, •Indicate significance of correlation at $p<0.05$ and $p<0.01$, YP: Yield Productivity; YS: Yield Stress; MP: Mean Productivity; GMP: Geometric Mean Productivity; STI: Stresses Tolerance Index

Table 5: Correlation coefficient of drought resistant indices in generative stress

Parameters	YP	YS	MP	GMP	STI	SSI	TOL
YP	1	0.427••	0.921••	0.753••	0.707••	0.328	0.816••
YS		1	0.746••	0.912••	0.918••	-0.657••	-0.714
MP			1	0.948••	0.916••	-0.041	0.526
GMP				1	0.98••	-0.313	0.237
STI					1	-0.345	0.183
SSI						1	0.766••
TOL							1

••, •Indicate significance of correlation at $p<0.05$ and $p<0.01$, YP: Yield Productivity; YS: Yield Stress; MP: Mean Productivity; GMP: Geometric Mean Productivity; STI: Stresses Tolerance Index

Fernandez (1992) believes that the best criterion for selection could clarify genotypes with same emergence in both stress and non-stress conditions. To determine proper indices, those criteria with high correlation to yield are selected. The result indicated that MP, GMP and STI have positive and significant correlation with both YP and YS, but TOL and SSI have positive and significant correlation with YS (Table 4 and 5). MP, GMP and STI could clarify A group genotypes (genotypes with same emergence in both stress and non-stress conditions) and are regarded as the best indices.

Table 4 shows that in vegetative-stress condition, yield correlation in both stress and non-stress conditions is significant (0.635). Yield in non-stress condition has positive and significant correlation ($p<0.01$). Yield in stress condition has negative correlation (-0.614) ($p<0.01$), but no correlation was detected with TOL. Other indices in stress condition have positive and significant correlation with yield.

In generative-stress condition (Table 4), grain yield correlation in both stress and non-stress conditions is significant (0.427) ($p<0.5$). Grain yield in non-stress condition with all indices, except SSI, has negative and significant correlation (-0.657) ($p<0.01$). No correlation was found with TOL. Grain yield in stress condition with other indices has positive and significant correlation.

We conclude that conventional selection of inbred lines maize populations in generally favorable international environments, as currently conducted, results in improvement in resistance to drought. This is confirmed by analyses effects which showed that the two selection environments are largely independent (Denmead *et al*., 1999). This perhaps is not surprising, since the stress used during selection for drought tolerance was quite severe and occurred during every selection cycle. Under these conditions, favorable traits, such as grain yield and capacity to recover from stress, would have a direct effect on productivity in each selection cycle. At the same time, genetic variation for constitutive traits affecting stress tolerance and productivity, such as partitioning to the ear, is effectively and rapidly exposed under managed water deficits. As drought stress intensifies, the flux of assimilate to the ear approaches, and for same cultivar crosses, a threshold needed to form a fertile ear (Edmeads *et al.*, 1992). Barrenness, or its commonly used equivalent, ears per plant, can then provide an easily observable measure of drought resistance in the field.

CONCLUSIONS

Historically, maize improvements in grain yield have been due to a variety of factors, one of which is greater resistance to environmental stress. This improvement has been attributed to enhanced performance of parental inbred lines in part due to resistance to water-deficit stress. For maize, the period during pollination and early grain filling is the most sensitive to water stress as compared with pre flowering and late grain-filling growth stages. To achieve efficient selection for drought resistance, the selection process must include the best indices for introducing superior lines and managed environments where the timing, duration and intensity of the water-deficit stress can be controlled.

MP, GMP and STI could clarify A group genotypes (genotypes with the same emergence in both stress and non-stress conditions). Although careful classification of environments and measurements of factors affecting the environments are also needed to help reduce the current resources dedicated to wide-area testing in stress-related breeding programs.

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