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# Effect of Drought and Seasons on Performance and Stability of Maize Genotypes

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**Abstract:** Twenty single cross hybrids developed by crossing ten elite inbred lines with two drought tolerant exotic testers (viz. CML-341 and Pool 16 BN) in line x tester mating design, were evaluated along with parental lines and three checks under rainfed (during kharif 2004), normal irrigation and terminal drought (during rabi 2004-05). Hybrids (F'1s) exhibited higher grain yield, plant height and ear length along with reduced ASI and earliness over parental lines under all the environments, indicated that hybrids had better growth and vigor as compared to their inbred parental lines. Traits under investigation were controlled by both additive ($\sigma^2$ A) and non-additive ($\sigma^2$ D) gene actions and thus could be improved through selection followed by hybridization. The parental line Pool 16 BN was found to be stable for grain yield and anthesis-silking interval (ASI), while inbred EI-573 was better under water stress environment. Hybrid (EI-569 x CML-341) was stable for grain yield and found suitable under moisture stress environment for ASI. The early hybrids (EI-572 x Pool 16 BN) and (EI-571 x Pool 16 BN) found suitable under high yielding environments for grain yield, while for ASI these hybrids were suitable under favorable and unfavorable environments, respectively. Navjot was also found appropriate under moisture stress environments.

**Key words:** Exotic tester, terminal drought, genotype, genotype x environment interaction.

In Rajasthan, especially in southern part of the state, maize (*Zea mays* L.) is an important cereal crop. In this region about 80-90% area under maize cultivation is rainfed, which generally faces terminal drought and yields are low (<1.0 t $ha^{-1}$). Drought is a multi-dimensional stress, affecting plants at various levels of their organization. The effect of drought on various growth stages and response of plant to drought are most complex. Maize is very sensitive to moisture stress. In this crop there are three important growth stages viz. germination, flowering (i.e. tasseling and silking) and grain filling stage. Among these, flowering and grain filling are most critical stages in relation to water stress. Terminal drought stress occurs generally at these two stages (i.e. flowering and grain filling), which adversely affects pollen viability; silk growth, silk receptivity and grain filling which ultimately cause drastic reduction in grain yield. The improvement in yielding ability of maize under drought largely depends on drought resistance/tolerance of the genotypes. The present investigation was undertaken to observe effects of terminal drought and seasons (i.e. kharif and rabi) on performance of maize genotypes as well as identifying stable and drought tolerant/resistant genotypes.

## Materials and Methods

Ten elite inbred lines (EI-569, EI-570, EI-571, EI-572, EI-573, EI-574, EI-575, EI-576, EI-577 and EI-578) were crossed with two drought tolerant exotic testers (viz. CML-341 and Pool 16 BN) in line x tester mating design to develop 20 single cross hybrids. These hybrids along with 12 parental lines and 3 checks (viz. CM-137, PEHM-2 and Navjot) were evaluated in randomized block designs with 3 replications under 3 environments [$E_1$=Rain fed during kharif 2004 (late sown); $E_2$=Normal irrigation during rabi 2004-05 and $E_3$=Terminal drought (withholding irrigation at and after flowering stage), during rabi 2004-05] with a spacing of 60 cm and 25 cm between rows and plants, respectively, in each environment. The experiments were conducted at the Instructional Farm, Rajasthan Collage of Agriculture, MPUAT, Udaipur. The observations were recorded for days to 50% pollen shed, days to 50% silking, anthesis-silking interval (ASI), days to 50% maturity, plant height (cm), ear length and grain yield per plant. The superior inbreds and hybrids were identified on the basis of *per se* performance, genotype x environment interactions and stability parameters. The standard statistical procedure suggested by Eberhart and Russell (1966) was adopted for analysis of data.

## Results and Discussion

The mean squares from joint regression analysis (Table 1) expressed highly significant estimates for all the traits. Test genotypes possessed appropriate genetic variation, environments had significant effect on expression of traits. and genotypes significantly interacted with environmental fluctuations. Highly significant variances due to genotype x environment (linear) and pooled deviation indicated that traits under study were controlled by both linear (additive, $\sigma^2$ A) and non-linear (non- additive, $\sigma^2$ D) gene actions. Kumar and Singh (2004) also observed significant variances for genotypes, environment (linear), genotype x environment (linear) and pooled deviation.

*Table 1. Mean squares from joint regression analysis for seven traits in maize*

| Source | d.f. | Days to 50% pollen shed | Days to 50% silking | Anthesis-silking interval (days) | Days to 50% maturity | Plant height (cm) | Ear length (cm) | Grain yield (g plant$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Genotype | 34 | 16.94** | 21.17** | 1.78** | 3.95** | 710.37** | 267.16** | 1428.17** |
| Environment | 2 | 24.22** | 1079.48** | 136.99** | 94.42** | 86.33** | 191125.68** | 1668.34** |
| E+(G x E) | 70 | 847.03** | 906.21** | 3.15** | 1179.13** | 1943.84** | 368.69** | 2446.94** |
| Environment (Linear) | 1 | 58903.74** | 62923.28** | 129.26** | 82410.06** | 124221.41** | 18063.71** | 127417.12** |
| G x E (Linear) | 34 | 4.07** | 6.13** | 2.09** | 1.69** | 212.60** | 138.91** | 1075.68** |
| Pooled deviation | 35 | 7.15** | 8.66** | 0.57** | 2.04** | 131.98** | 86.34** | 208.44** |
| Pooled Error | 204 | 0.32 | 0.30 | 0.16 | 0.31 | 5.82 | 4.48 | 5.45 |

*,** Significant at 5 and 1% level, respectively.

The general, parental and $F_1$s mean values (Table 2) revealed that performance of genotypes was highly influenced by seasons as well as drought. Days to pollen shed and silking were earlier during kharif than rabi by 48-50 days in various groups of genotypes. The blooming delayed by 3-5 days under drought conditions in comparison to irrigated environment. Anthesis-silking interval was affected less by seasons (i.e. kharif and rabi) as compared to other traits. Under water stress conditions ASI increased more than two-fold over the normal. Maturity was delayed in rabi season than kharif by 60-62 days. Under water stress conditions maturity was enhanced by 4 days over irrigated conditions. The mean plant height and ear length was maximum during kharif followed by rabi irrigated, while it was significantly reduced under terminal water stress. Mean grain yield per plant was highest under normal irrigation during rabi (146.70 g) followed by under terminal drought conditions (73.37 g) and kharif (72.26 g). It was also observed that hybrids ($F_1$'s) exhibited higher grain yield, plant height and ear length along with reduced ASI and earliness in pollen shedding, silking and maturity over parental lines under all the environments. Thus, it was expected that hybrids had better growth and vigor as compared to their inbred parental lines. Saleh *et al.* (2002) also observed early in flowering and maturity in hybrids than their respective inbred parents.

The estimates of linear and non-linear components of genotype x environment interaction also suggested that all the traits were controlled by both additive ($\sigma^2 A$) and non-additive ($\sigma^2 D$) gene actions (Table 3). The predominancy of linear component was observed for ASI (74.29%) and days to maturity (57.14%), while non-linear component was predominant for days to pollen shed (62.82%) and silking (65.71%), plant height (65.71%), ear length (62.82%) and grain yield per plant (82.86%). Therefore, these traits could be improved through selection followed by hybridization.

The performance of a genotype could not be predicted unless it possessed non-significant deviation from regression ($S^2_{di}$=0). The distribution of 35 genotypes (Table 4) revealed that 26 genotypes exhibited non-significant $S^2_{di}$ for ASI and it could be treated as the most stable trait followed by days to maturity (20), days to pollen shed (13), ear length (13), plant height (12), days to silking (12) and grain yield per plant (6). For other genotypes exhibiting significant deviation from regression ($S^2_{di}$>0), suggested that the performance could not be predicted in other conditions based on their performance observed in three environments of this study.

The stable parental lines and hybrids were identified on the basis of individual stability parameters (Table 5). Eberhart and Russell (1966) proposed that stable genotypes would be those, which possessed unit regression coefficient ($b_i$=1), non-significant deviation from regression ($S^2_{di}$=0) and higher mean performance over population mean in desired direction. The genotype exhibiting above ($b_i$>1) and below ($b_i$<1) average response supposed to perform better under favorable and unfavorable environments, respectively. The ASI and grain yield are the most important traits for screening the genotypes under moisture stress environments. The genotypes with reduced ASI and higher grain yield would express better performance under drought

*Table 2. General, parental and $F_1$'s mean values for seven traits in maize*

| Trait | Parameter | Mean values | | | SE (d), CD |
|---|---|---|---|---|---|
| | | Rainfed kharif, 2004 | Irrigated rabi, 2004-05 | Terminal drought rabi, 2004-05 | |
| Days to 50% pollen shed | General mean | 49.14 | 97.93** | 100.72++ | SE (d) = 0.135 |
| | Parental mean | 50.11 | 98.69** | 102.50++ | CD 5% = 0.265 |
| | F1's mean | 48.30 | 96.70** | 99.17++ | CD 1% = 0.349 |
| | SEm± | 0.57 | 0.50 | 0.62 | |
| | CV (%) | 2.02 | 0.89 | 1.06 | |
| Days to 50% silking | General mean | 51.21 | 100.56** | 105.38++ | SE (d) = 0.132 |
| | Parental mean | 52.33 | 101.61** | 106.81++ | CD 5% = 0.259 |
| | F1's mean | 50.25 | 99.00** | 103.93++ | CD 1% = 0.340 |
| | SEm± | 0.60 | 0.53 | 0.52 | |
| | CV (%) | 2.04 | 0.92 | 0.85 | |
| Anthesis-Silking Interval (days) | General mean | 2.10 | 2.60** | 4.67++ | SE (d) = 0.095 |
| | Parental mean | 2.22 | 2.81** | 4.36++ | CD 5% = 0.186 |
| | F1's mean | 1.98 | 2.32** | 4.75++ | CD 1% = 0.244 |
| | SEm± | 0.28 | 0.45 | 0.44 | |
| | CV (%) | 23.03 | 29.72 | 16.38 | |
| Days to 50% maturity | General mean | 78.76 | 140.17**++ | 135.99 | SE (d) = 0.133 |
| | Parental mean | 79.25 | 139.61**++ | 135.75 | CD 5% = 0.260 |
| | F1's mean | 78.30 | 140.35**++ | 135.78 | CD 1% = 0.342 |
| | SEm± | 0.52 | 0.54 | 0.60 | |
| | CV (%) | 1.15 | 0.67 | 0.76 | |
| Plant height (cm) | General mean | 219.52** | 160.56++ | 137.92 | SE (d) = 0.576 |
| | Parental mean | 209.22** | 151.33++ | 118.92 | CD 5% = 1.129 |
| | F1's mean | 224.88** | 165.00++ | 147.20 | CD 1% = 1.485 |
| | SEm± | 3.14 | 2.53 | 1.11 | |
| | CV (%) | 2.47 | 2.73 | 1.40 | |
| Ear length (cm) | General mean | 96.04** | 78.16++ | 63.98 | SE (d) = 0.506 |
| | Parental mean | 91.06** | 72.22++ | 55.31 | CD 5% = 0.992 |
| | F1's mean | 98.52** | 80.20++ | 67.20 | CD 1% = 1.303 |
| | SEm± | 3.13 | 1.78 | 0.70 | |
| | CV (%) | 5.64 | 3.95 | 1.89 | |
| Grain yield (g $plant^{-1}$) | General mean | 72.26 | 146.70**++ | 73.37 | SE (d) = 0.312 |
| | Parental mean | 65.89 | 106.78**++ | 62.97 | CD 5% = 0.611 |
| | F1's mean | 77.43 | 175.97**++ | 80.47 | CD 1% = 0.802 |
| | SEm± | 2.03 | 3.36 | 0.98 | |
| | CV (%) | 4.87 | 3.96 | 2.31 | |

** Significant difference between kharif and rabi at 1% level.

++ Significant difference between rabi irrigated and rabi terminal drought at 1% level.

*Table 3. Magnitude (%) of linear and non-linear component of G x E interaction for seven traits in maize*

| Trait | Linear component | Non-linear component |
|---|---|---|
| Days to 50% pollen shed | 37.14 | 62.86 |
| Days to 50% silking | 34.29 | 65.71 |
| Anthesis-Silking Interval | 74.29 | 25.71 |
| Days to 50% maturity | 57.14 | 42.86 |
| Plant height | 34.29 | 65.71 |
| Ear length | 37.14 | 62.86 |
| Grain yield/plant | 17.14 | 82.86 |

conditions. The parental line Pool 16 BN was found to be stable for grain yield and ASI, showing slightly late silking. Hybrid (EI-569 x CML-341) was stable for grain yield and was suitable under poor environment for ASI along with early silking. Inbred EI-573 was better under water stress environment having reduced ASI, early silking and slightly low grain yield over population mean. However, this inbred showed higher grain yield over Navjot. Hybrid (EI-572 x Pool 16 BN) found suitable under high yielding environment for grain yield and ASI along with early silking. The early hybrid (EI-571 x Pool 16 BN) was suitable under favorable environments for grain yield, while under unfavorable environment for ASI. The standard check Navjot was also found appropriate under poor environments with low grain yield and enhanced silking and ASI. Reddy *et al.* (2004) also identified

*Table 4. Distribution of thirty-five genotypes on the basis of two stability parameters for predictability of performance for seven traits in maize*

| Trait | Predictable ($S^2_{di}$ non-significant) | | | | | | | Unpredictable ($S^2_{di}$ significant) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $b_i$ non-significant | | | $b_i$ significant | | | | $b_i$ non-significant | | | $b_i$ significant | | | |
| | I* | H* | C* | I* | H* | C* | Total | I* | H* | C* | I* | H* | C* | Total |
| Days to 50% pollen shed | - | - | - | 4 | 7 | 2 | 13 | 5 | 10 | - | 3 | 3 | 1 | 22 |
| Days to 50% silking | - | - | - | 2 | 9 | 1 | 12 | 9 | 7 | 1 | 1 | 4 | 1 | 23 |
| Anthesis-silking Interval | 6 | 11 | 1 | 4 | 4 | - | 26 | - | - | - | 2 | 5 | 2 | 9 |
| Days to 50% maturity | - | - | - | 9 | 10 | 1 | 20 | 3 | 9 | 2 | - | 1 | - | 15 |
| Plant height | - | - | - | 6 | 5 | 1 | 12 | - | - | - | 6 | 15 | 2 | 23 |
| Ear length | 1 | 3 | 2 | 4 | 3 | - | 13 | - | - | - | 7 | 14 | 1 | 22 |
| Grain yield/plant | - | - | - | 2 | 3 | 1 | 6 | - | 6 | 1 | 10 | 11 | 2 | 29 |

I* = Inbred , H* = Hybrid, C* = Check.

*Table 5. Estimates of stability parameters for days to 50% silking, anthesis-silking interval and grain yield per plant in maize*

| Pedigree | Days to 50% silking | | | Anthesis-silking interval (days) | | | Grain yield per plant (g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\mu_i$ | $b_i$ | $S^2_{di}$ | $\mu_i$ | bi | $S^2_{di}$ | $\mu$i | bi | $S^2_{di}$ |
| Pool 16 BN | 88.33 | 1.14 | 18.90** | 3.00 | 0.92 | 0.24 | 106.89 | 1.00** | -5.30 |
| EI 573 | 83.67 | 0.92* | 3.00** | 2.56 | 0.28 | -0.15 | 89.78 | 0.87* | -4.11 |
| EI 569 x CML 341 | 84.78 | 1.01* | 8.61** | 2.11 | 0.37 | -0.15 | 105.56 | 1.06* | 4.76 |
| EI 571 x Pool 16 BN | 80.89 | 0.94* | 8.51** | 3.11 | 0.79* | -0.16 | 109.11 | 1.11* | 4.37 |
| EI 572 x Pool 16 BN | 87.56 | 1.10 | 85.40** | 4.00 | 2.74 | 0.38 | 116.89 | 1.73** | -5.42 |
| Navjot (c) | 91.44 | 1.06 | 35.70** | 4.33 | 0.87 | 5.25** | 88.67 | 0.56* | 1.12 |
| Population Mean | 85.72 | 1.00 | 0.00 | 3.12 | 1.00 | 0.00 | 97.44 | 1.00 | 0.00 |

*,** Significant at 5 and 1% level, respectively.

stable hybrids for grain yield and its contributing traits.

Thus, it could be concluded that genotypes were highly influenced by season as well as water stress conditions. Hybrids ($F_1$'s) exhibited higher grain yield, plant height and ear length along with reduced ASI and earliness over parental lines under each environment, indicating that hybrids had better growth and vigor as compared to their inbred parental lines. The parental line Pool 16 BN was found to be stable for grain yield and ASI, while inbred EI-573 was better under water stress environment having reduced ASI and early silking. Hybrid (EI-569 x CML-341) was stable for grain yield and was suitable under drought environment for ASI with early silking. The early hybrids (EI-572 x Pool 16 BN) and (EI-571 x Pool 16 BN) found suitable under favorable environments for grain yield, while for ASI these hybrids were suitable under favorable and unfavorable environments, respectively. Navjot was also found appropriate under moisture stress environments. These hybrids could commercially be cultivated after further evaluation in multilocation yield trials, whereas inbred lines could be utilized in further maize breeding programmes for drought tolerance.

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