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**Research Article**

# Combining ability for yield and yield attributing traits under moisture stress environments in maize (*Zea mays* (L.)

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**Abstract**
Ninety one cross combinations along with 14 selected drought tolerant tropical parental lines were assessed for their combining ability in maize. The ratio of GCA:SCA variance showed the predominanace of non additive gene action for important yield contributing traits *viz.*, cob length,cob girth, number of kernel rows per cob, number of kernels per row, grain yield per plant and protein content and would be improved by heterosis breeding.The traits such as days to 50 % tasseling and silking,ASI, days to maturity,plant height, hundred grain weight,RWC,root volume,root length and starch content had predominantly additive gene action.Based on the *per se* performance and *gca* effects, the parents P1,P2,P3 and P4 were found to be superior parents to develop hybrids with enhanced yield through improving yield related characters under moisture stress environments.Considering *per se* performance and *sca* effects,out of six hybrids which were found to be promising, P4 X P6 and P4 X P5 possessed desirable *per se* performance and *sca* effects for grain yield per plant, kernel rows per cob, number of kernels per row,100 grain weight,RWC,protein and starch content.The hybrids noticed additive X additive type of interaction can be exploited for the development of single cross hybrid under moisture stress environment and also through the population improvement programme in the development of suitable early composite or synthetic.

**Key words**
Maize, moisture stress,diallel,combining ability,gene action,grain yield.

## Introduction

Today maize is one of the most important food and feed crops in the world. It is grown in more than 166 countries for diverse uses, in diverse seasons, in different agro-ecological conditions due to its high yield potential. In India, maize is grown in a wide range of climates, extending from extreme semi-arid to sub-humid to temperate conditions. So, 80 per cent of the maize area at present is confined to rainfed condition and often suffers from abiotic stresses. This is one of the major reasons for low productivity of maize in India.

Moisture deficit is the most common limiting abiotic stress among all stresses and it is one of the major constraints in maize productivity. Moisture stress is very common in the areas where maize is predominantly grown during kharif season under rainfed conditions. But, drought and low N stresses are major factors most frequently limiting the maize production in the tropics. Maize is susceptible to drought at flowering stage than any other crop[6]. Drought leads to reduced leaf, silk, stem, root and grain development[1].It was also found that varieties of maize exposed to unpredictable drought stress during the growing season produced low grain yield[3]. In Krishnagiri and Dharmapuri districts of Tamil Nadu, maize is being grown as a rainfed crop for late Kharif season (September – October). These two districts are drought prone areas in Tamil Nadu state. Moisture stress is one of the most important constraints to maize production in this region. In this districts, a total area of 3000 ha comes under maize cultivation as rainfed. The annual rainfall in these districts varied from 850 to 950 mm per year with more than 80% of the rainfall received during North East monsoon (October – November). During rainfed situation, drought prolong the anthesis to silking interval resulting in poor kernel set and can lead to more than 50% yield reduction or in some cases, complete crop loss occur. Most of the hybrids and composites developed so far may not be able to tolerate the prolonged moisture stress. Breeding for genotypes suitable for rainfed under moisture stress conditions will be much useful to the farmers and industries of the districts. Testing sites include research station as well as farmers field representing the most major corn growing locations.

The cultivation of single cross hybrid maize has helped in mitigating severity of stresses to some extent because of their inherent ability to perform well under stress conditions compared to open pollinated varieties. The reasons for better performance of single cross hybrid over OPV’s are *viz.*, better root system, early vigour and quick growth competes with weeds. Improvement of productivity of maize cultivars under drought conditions becomes one of the objectives of breeding programmes in maize. Combining ability analysis is extensively used to study the nature and magnitude of gene action and to facilitate correct choice of parents in a hybrid breeding programme. The knowledge of gene effects operative in expression of trait greatly helps the plant breeders in making correct decision about breeding materials, selection method, type of variety and extent of testing. Keeping this in view,the present investigation was undertaken to determine the general combining ability of parental lines and specific combining ability of cross combinations.

**Materials and methods**

The present investigation on genetic studies for drought tolerance in maize was carried out under moisture stress in rainfed and induced environments during the year 2008-2010 at the Regional Research Station, Paiyur, Krishnagiri district and in farmers holding at Dharmapuri district. Ninety one F1 single cross hybrids generated from diallel fashion, their parents (Table 1) and single cross hybrid check CoH(M)5 were tested at four locations both under rainfed and induced moisture stress conditions. The first set of experiments were conducted at Regional Research Station, Paiyur under rainfed and moisture stress induced conditions during August 2009. The second set of experiments were also organized in maize growing areas of Dharmapuri district in farmers holding both under rainfed and moisture stress induced conditions during August 2010 i.e. moisture stress rainfed (E1) at RRS, Paiyur (L1-2009) and farmers holding (L3-2010); moisture stress induced (E2) at RRS, Paiyur (L2-2009) and farmers holding (L4-2010) and overall environments (E3) (L1-L4).

The experiments were conducted in a randomized block design (RBD) with two replications. The plots were 4m length each in two rows with a spacing of 60cm between rows and 25cm between plants.Recommended agronomic practices were followed for all the trials..

The rainfed sowing was dependent on the monsoon, which starts by the middle of August, but rainfall distribution was erratic and can result in drought conditions at critical crop stages particularly during flowering for both years (2009, 2010). Drought was often experienced during the last week of September often coinciding with flowering.

The moisture stress induced experiment (E2) was planted for the year 2009 and 2010. Irrigation water was applied at planting to establish a good plant stand. Two weeks before silking, irrigation was withheld so that the crop was exposed to drought stress during flowering. The observations were recorded in each entry, in each replication and in each season on five randomly selected competitive plants excluding border plants and their mean values were computed for statistical analysis using TNAUSTAT and GENERES packages.The analysis of data for general and specific combining ability effects was done as per method II (without reciprocals),model 1 as suggested by [2].

**Results and discussion**

The combining ability analysis across environments(Table 2) showed the highly significant GCA and SCA variances for all the traits studied indicating the importance of both additive and non-additive gene action for the expression of the traits under moisture stress environment The ratio of additive : non-additive variance was greater than one for all the traits studied except cob length, cob girth, number of kernel rows, number of kernels per row, grain yield per plant and RWC in overall environments under moisture stress indicating the additive type of gene effects were more important in the expression of days to tasseling, days to silking, anthesis silking interval, days to maturity, plant height, 100 grain weight, root volume, root length, starch and protein content and thus simple selection would yield rapid for improvement of these characters. Non-additive type of gene effects were more prominent for cob length, cob girth, number of kernel rows, number of seeds per row, grain yield per plant and RWC. Selection for these traits could be delayed to later generations until the non-additive portion had mitigated to additive portion as these characters showed higher magnitude of SCA variance than GCA variance in overall environments under moisture stress conditions. Similar results were obtained by[4,5,7].The knowledge of .general combining ability coupled with high *per se* of parents (Table 3)would be of great value in single cross hybrid maize breeding programme under moisture stress conditions. Authenticity of *gca* effect, guaranteed by matching *per se* performance facilitate the breeder in selecting suitable parents under target environments for hybrid breeding or synthetic variety development programme.

In the present study, desirable mean value and *gca* effects were possessed by the parents *viz*., P3, P11 and P12 for days to 50 per cent tasseling, silking and days to maturity (early duration), P1, P2 and P10 for ASI, P1, P2 and P3 for plant height, P2, P10 and P4 for number of kernels per cob, P1, P2, P3 and P4 for grain yield per plant, P3 and P6 for number of kernels per row, P2, P3, P4 and P6 for 100 grain weight, P3 for cob length, P6 and P9 for root length, P7 for root volume, P6 and P5 for protein content and P6 for starch content.

The parents with high *per se* performance as well as high *gca* could produce superior segregants in F2 as well as in later generations. Considering the overall assessment of yield components for high *gca* and *per se* performance (Table 3), a close correspondence between mean performance and *gca* effect was observed among the parents under moisture stress in E1, E2 and E3 environments. It is known from the above study that the parents differ in their combining ability for different traits and that no parent can be a good combiner for all traits under moisture stress environments (E1, E2 and E3). However, only four parents *viz*., P1, P2, P3 and P4 possessed desirable mean and *gca* effects for grain yield per plant under all moisture stress environmental conditions.

For exploiting hybrid vigour, *per se* performance, *sca* effects of hybrids are important and are presented in Table 4. Selection based on any one of these criteria alone may not be effective. The hybrids with high *per se* performance need not always reveal high *sca* effect and vice versa. So, selection must be based on all the parameters. In the present study also, the hybrids were evaluated on the basis of the above said two parameters.

Among the 91 hybrids, analyzed under water stress condition during flowering periods, hybrids *viz*., P4 x P6 and P4 x P5 was identified as the best hybrids in all environments (rainfed and induced) since it possessed desirable *per se* performance and *sca* for grain yield per plant, kernel rows per cob, Number of kernels per row, 100 grain weight, RWC, protein and starch content. The hybrids P2 x P8 for grain yield, number of kernels per cob, reduced ASI and early flowering and maturity .

The hybrids P3 x P5 and P1 x P11 showed desirable performance for cob length and grain yield per plant. Followed by P2 x P11 for reduced ASI and grain yield per plant, P3 x P4 for plant height and grain yield, P7 x P8 for early silking and maturity, P2 x P10 for cob length and P1 x P9 for cob girth .

The results obtained in the present investigation were encouraging and tremendous increase in yield was obtained in stable performing hybrids in overall the environments under water deficit conditions. For more effective selection of a hybrid, besides *per se and sca* effect , the hybrid should have both the parents as good combiners or at least any one of the parent as a good combiner. In the present study, it was observed that the hybrids *viz.*, P4 x P6, P4 x P5, P2 x P8, P3 x P5, P1 x P11 and P3 x P4 and P1 x P9 showed good *per se and sca* , had one of the parents as a good combiner.

It is understood from the above that the hybrids which showed high *sca* mostly involved high x low *gca* effects and high x high *gca* effects, which indicates the presence of both additive x dominance and additive x additive type of interaction. Hence, those hybrids showing additive x dominance type of interaction under moisture stress can be forwarded to advance generation and these crosses may be grown for isolation of desirable transgressive segregants [8].However, the performance of top ranking hybrids need to be further evaluated in on farm and multi location trials under moisture deficit conditions prior to commercial exploitation. The hybrids with additive x additive type of interaction can be exploited for the development of single cross hybrid under moisture stress environments and also through the population improvement programme in the development of suitable early composite or synthetic after knowing the inbreeding depression in F2 and subsequent generations.

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Tae 1. Parents used in crossing

| Genotypes | Code |
|---|---|
| UMI 285 | P1 |
| UMI 1085 | P2 |
| UMI 1058 | P3 |
| UMI 233 | P4 |
| UMI 1096 | P5 |
| UMI 1069 | P6 |
| UMI 1054 | P7 |
| UMI 1060 | P8 |
| UMI 1029 | P9 |
| UMI 1024 | P10 |
| UMI 1019 | P11 |
| UMI 1009 | P12 |
| UMI 917 | P13 |
| UMI 61 | P14 |

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Table 2. Analysis of variance for combining ability over environments (Diallel analysis)

| Characters | GCA | SCA | Environments | GCA x Env. | SCA x Env. | ERROR | GCA / SCA |
|---|---|---|---|---|---|---|---|
| df | 13 | 91 | 3 | 39 | 273 | 416 | |
| DT | 27.12** | 19.01** | 197.53** | 4.11** | 3.93** | 0.25 | 1.427 : 1 |
| DS | 29.21** | 20.73** | 185.65** | 4.07** | 4.87** | 0.3 | 1.404 : 1 |
| ASI | 1.55** | 0.94** | 1.50** | 0.33** | 0.52** | 0.096 | 1.699 : 1 |
| DM | 29.21** | 20.73** | 185.65** | 4.07** | 4.87** | 0.3 | 1.409 : 1 |
| PH | 3235.68** | 396.77** | 4075.94** | 12.85** | 11.50** | 0.9 | 8.155 : 1 |
| CL | 0.83** | 1.33** | 139.66** | 0.49** | 0.40** | 0.22 | 0.624 : 1 |
| CG | 0.09** | 0.56** | 26.84** | 0.61** | 0.40** | 0.24 | 0.161 : 1 |
| KR | 1.79** | 4.39** | 37.17** | 1.37** | 0.81** | 0.07 | 0.408 : 1 |
| NK | 15.38** | 19.60** | 430.80** | 4.24** | 3.46** | 0.26 | 0.715 : 1 |
| 100 GW | 17.19** | 11.92** | 330.42** | 4.31** | 3.18** | 0.2 | 1.442 : 1 |
| GY | 1590.74** | 1664.24** | 31907.35** | 159.92** | 150.95** | 4.96 | 0.735 : 1 |
| RWC | 54.54** | 74.17** | 2212.46** | 12.74** | 6.37** | 0.68** | 0.956 : 1 |
| RV | 120.44** | 47.55** | 195.66** | 2.63** | 3.15** | 1.57 | 2.533 : 1 |
| RL | 151.37** | 68.67** | 181.95** | 2.69** | 2.71** | 1.4 | 2.204 : 1 |
| PL | 0.40** | 0.68** | 37.23** | 0.16** | 0.15** | 0.02 | 1.588 : 1 |
| SC | 50.55** | 44.96** | 1304.83** | 19.16** | 14.69** | 11.09 | 1.124 : 1 |

| | | | |
|---|---|---|---|
| DT – Days to 50% tasseling | PH – Plant height (cm) | NK – No. of kernels | RV – Root volume ($m^2$) |
| DS – Days to 50% silking | CL – Cob length (cm) | 100 GW – 100 grain weight (g) | RL – Root length (cm) |
| ASI – Asthesis silking interval (days) | CG – Cob girth | GY – Grain Yield / plant (g) | PC – Protein content (%) |
| DM – Days to maturity | KR – Kernel rows | RWC – Relative water content | SC – Starch content (%) |

Table 3. Best parents based on mean performance and *gca* effects in moisture stress environments

| Sl. No | Genotypes | E1 | | E2 | | E3 | | Mean and gca | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Per se | gca | Per se | gca | Per se | gca | E1 | E2 | E3 |
| 1. | Days to 50 % tasseling | P3, P11, P12, P13 | P11, P3, P2, P12 | P3, P14, P11, P10 | P11, P3, P12, P10 | P3, P11, P14, P12 | P11, P3, P2, P12 | P3, P11, P12 | P3, P11, P12 | P3, P11, P12 |
| 2. | Days to 50 % silking | P12, P3, P11, P13 | P11, P3, P2, P12 | P14, P3, P11, P10 | P11, P2, P3, P10 | P3, P11, P14, P12 | P11, P3, P2, P12 | P3, P11, P12 | P3, P10, P11 | P3, P11, P12 |
| 3. | ASI | P10, P6, P1, P2 | P1, P4, P2, P10 | P1, P2, P14, P6, P10 | P1, P2, P5, P10 | P1, P2, P6, P10 | P1, P2, P10, P4 | P10, P1, P2 | P1, P2, P10 | P1, P2, P10 |
| 4. | Days to maturity | P12, P3, P11, P14 | P11, P3, P2, P12 | P14, P3, P11, P10 | P11, P2, P3, P10 | P3, P11, P14, P12 | P11, P3, P2, P12 | P3, P11, P12 | P3, P10, P1 | P3, P11, P12 |
| 5. | Plant height | P3, P2, P1, P5 | P1, P2, P3, P5 | P1, P2, P3, P4 | P1, P2, P3, P4 | P3, P2, P1, P5 | P1, P2, P3, P6 | P1, P2, P3, P5 | P1, P2, P3, P4 | P1, P2, P3 |
| 6. | Cob length | P4, P3, P5, P8 | P1, P8, P5, P4 | P4, P11, P5, P7 | P2, P7, P3, P4 | P4, P5, P3, P11 | P1, P2, P7, P3 | P4, P5, P8 | P4, P7 | P3 |
| 7. | Cob girth | P3, P4, P10, P8, P6 | P13, P1, P2, P14, P8 | P3, P4, P12, P6, P9 | P1, P2, P9, P10, P3 | P3, P4, P12, P6, P9 | P1, P2, P13, P10 | -- | P3, P9 | -- |
| 8. | Number of kernel rows | P8, P13, P10, P3, P4 | P13, P10, P4, P2, P3 | P8, P5, P10, P4, P2 | P1, P2, P3, P4, P5 | P8, P10, P13, P4, P2 | P2, P1, P3, P4, P10 | P13, P10, P3 | P5, P4, P2 | P4, P2, P10 |

Table 3 :Best parents based on mean performance and gca effects in moisture stress environments (contd.)

| Sl. No | Genotypes | E1 | | E2 | | E3 | | Mean and gca | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Per se | gca | Per se | gca | Per se | gca | E1 | E2 | E3 |
| 9. | Number of kernels / row | P14, P1, P10, P4, P13 | P4, P6, P2, P3, P1 | P4, P1, P14, P8, P7 | P4, P6, P2, P3, P1 | P4, P1, P14, P8 | P4, P1, P8, P3, P6 | P1, P4 | P4, P1 | P3, P4, P6 |
| 10. | 100 grain weight | P3, P4, P2, P7, P6 | P2, P1, P4, P6, P5 | P6, P11, P3, P9 | P1, P3, P11, P6, P7 | P3, P6, P11, P4, P2 | P1, P2, P3, P6, P4 | P2, P4, P6 | P3, P6, P11 | P3, P6, P4, P2 |
| 11. | Grain yield / plant | P3, P4, P2, P1, P7 | P4, P1, P2, P3, P6 | P4, P13, P1, P3, P10 | P1, P3, P2, P4, P5 | P4, P3, P2, P13, P7 | P1, P2, P4, P3, P6 | P1, P2, P3, P4 | P1, P3, P4 | P1, P2, P3, P4 |
| 12. | RWC | P7, P4, P13, P1, P10 | P7, P10, P14, P8, P11 | P13, P7, P4, P14, P12 | P7, P6, P12, P11, P14 | P7, P13, P4, P9, P14 | P7, P12, P11, P14, P10 | P7, P10 | P7, P14, P12 | P7, P14 |
| 13. | Root volume | P12, P7, P11, P6, P14 | P7, P6, P12, P13, P14 | P7, P11, P9, P14, P12 | P7, P13, P6, P11, P12 | P7, P12, P11, P14, P9 | P7, P6, P13, P11, P12 | P12, P7, P6, P14 | P7, P11, P12 | P7, P12, P11 |
| 14. | Root length | P9, P12, P14, P6, P5 | P1, P3, P6, P9, P10 | P12, P10, P9, P7, P5, P6 | P1, P3, P6, P5, P9 | P12, P10, P9, P14, P6 | P1, P3, P6, P5, P9 | P6, P9 | P9, P6, P5 | P9, P6 |
| 15. | Protein content | P7, P2, P6, P8, P1 | P1, P6, P11, P2, P4 | P5, P6, P14, P10, P9 | P5, P4, P3, P11, P6 | P5, P6, P7, P2, P14 | P5, P6, P1, P11, P4 | P2, P6, P1 | P5, P6 | P5, P6 |
| 16. | Starch content | P12, P10, P4, P13, P3 | P6, P1, P2, P3, P5 | P4, P11, P6, P3, P2 | P6, P4, P2, P3, P5 | P4, P10, P3, P11, P6 | P6, P2, P3, P1, P5 | P3 | P4, P3, P6 | P3, P6 |

Table 4. Best hybrids based on overall mean performance and sca in moisture stress environments

| Sl. No | Genotypes | E1 | E2 | E3 |
|---|---|---|---|---|
| | | Per se and sca | Per se and sca | Per se and sca |
| 1. | Days to 50 % tasseling | P5 x P11, P2 x P8 | P10 x P12, P1 x P14 | P1 x P11 |
| 2. | Days to 50 % silking | P1 x P11, P2 x P8, P5 x P11 | P1 x P11, P3 x P6 | P1 x P11, P7 x P8, P2 x P8 |
| 3. | ASI | P2 x P8 | P2 x P11, P3 x P4, P1 x P11 | P2 x P8, P2 x P11 |
| 4. | Days to maturity | P1 x P11, P2 x P8, P5 x P11 | P1 x P11 | P7 x P8, P2 x P8 |
| 5. | Plant height | P3 x P4, P3 x P6 | P3 x P4 | P3 x P4 |
| 6. | Cob length | P1 x P11, P3 x P5, P2 x P13 | P3 x P5, P7 x P8 | P3 x P5, P1 x P11, P2 x P10 |
| 7. | Cob girth | P11 x P14 | P1 x P9, P6 x P11 | P1 x P9 |
| 8. | Number of kernel rows / cob | P4 x P6, P4 x P5, P2 x P8, P1 x P9 | P3 x P6, P4 x P5, P4 x P6 | P4 x P6, P4 x P5 |
| 9. | Number of kernels / row | P4 x P6, P4 x P5 | P4 x P6, P3 x P4, P2 x P8, P2 x P11 | P4 x P6, P4 x P5, P2 x P8 |
| 10. | Hundred grain weight | P4 x P6, P4 x P5, P2 x P8 | P3 x P5 | P4 x P5, P4 x P6 |
| 11. | Grain yield / plant | P4 x P6, P4 x P5, P2 x P8, P3 x P6, P3 x P5, P3 x P4 | P4 x P6, P4 x P5, P3 x P6, P3 x P5, P2 x P11, P3 x P4, P2 x P5, P1 x P11 | P4 x P6, P4 x P5, P3 x P5, P2 x P8, P2 x P11, P1 x P11, P3 x P4 |
| 12. | RWC | P4 x P6 | P4 x P6, P7 x P13 | P4 x P6, P9 x P12, P10 x P12 |
| 13. | Root volume | P6 x P14, P5 x P11 | P6 x P14, P2 x P12 | P2 x P12, P6 x P14 |
| 14. | Root length | P3 x P5, P6 x P7, P3 x P13, P1 x P11 | P5 x P11, P6 x P7, P1 x P12, P4 x P8 | P6 x P7, P3 x P13 |
| 15. | Protein content | P4 x P6, P4 x P5, P2 x P11, P2 x P5 | P4 x P6, P3 x P5, P1 x P8, P3 x P4 | P4 x P6, P4 x P5, P3 x P6, P1 x P9 |
| 16. | Starch content | P1 x P8, P2 x P3, P4 x P6, P4 x P5, P1 x P11 | P4 x P6, P2 x P5, P4 x P5 | P4 x P6, P4 x P5, P1 x P8 |