 

# Top Cross Analysis of Maize (Zea mays L) Inbred Lines for Some Agronomic Traits in Central Rift Valley of Ethiopia

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**Abstract**
Drought stress tolerant maize breeding program of Melkassa Agricultural Research Center (MARC) which is experimental farm of Ethiopian Institute of Agricultural Research (EIAR) in collaboration with CIMMYT has developed a large number of drought stress tolerant and/or early maturing elite maize inbred lines. The effort is aimed at identifying better combining inbred lines for the development of hybrids for drought stressed areas of the country as no hybrid maize variety has been released for this target area so far. To initiate effective hybrid breeding program, information on the combining ability of inbred lines is an essential and critical factor. In the current study, therefore, an attempt was made to generate information on 24 elite maize inbred lines crossed to two testers in line x tester mating fashion and evaluated the GCA and SCA effects of the inbred lines and the test cross performance of the hybrids for traits like date of emergence, anthesis to silkikng interval, days to maturity, number of kernels per row, number of rows per ear, stand count after thinning and biological yield. The genotypes were planted in 6x9 alpha lattice design replicated twice. Analysis of variance indicated significant mean squares due to genotypes for days to maturity, biomass yield, number of ears per plant and number of kernels per row which could be utilized for future evaluation for possible release or used in maize breeding activities. Highly significant differences were noticed among the crosses for biomass yield, number of kernels per row, number of ears per plant, number of rows per ear, indicating that the presence of numerous variations among each other for these traits. Similarly, mean squares due to SCA were highly significant for biomass yield, and number of kernels per row, and number of rows per ear.
**Keywords:** inbred lines, GCA, SCA

## 1. INTRODUCTION

To establish a sound basis for any breeding program, aimed at achieving higher maize production, breeders must have information on the nature of combining ability of parents, their behavior and performance in hybrid combination (Chawla and Gupta, 1984). Furthermore, such information also shows the type of gene action involved in controlling quantitative characters, thereby assisting breeders in selecting suitable parent materials (Hallauer and Miranda, 1988). Combining ability studies are also useful for classifying parental materials into distinct heterotic groups (Sprague and Tatum, 1942).
Although combining ability studies on maize inbred lines has been made in highlands (Twumasi *et al.,* 2001; Teshale, 2001 and Gudeta, 2007) and mid altitudes (Legesse *et al*., 2009; Mossisa *et al.,* 2009) of high potential maize growing areas of Ethiopia, little efforts have been done on low lands of the country on the performance of maize inbred lines. In the current study, therefore, an attempt was made to generate information on 24 elite maize inbred lines crossed to two testers of known heterotic groups in line x tester mating fashion and evaluated with the objectives to evaluate the test cross performance and to estimate the GCA and SCA effects of the inbred lines for grain yield and yield related traits.

## 2. MATERIALS AND METHODS

The experiment was carried out at MARC in 2010 main cropping season. A total of fifty two entries including 48 test crosses produced by crossing twenty four elite inbred lines with two testers (CML312/CML442, tester A and CML202/CML395, tester B) and four standard checks (BH540, BHQPY-545, Melkassa-2, Melkassa-6Q) were used for the study. The lines were obtained from MARC, but originally introduced from CIMMYT-Kenyan breeding program. The testers used in this study were identified by CIMMYT and are widely used in Africa by CIMMYT and many national maize breeding programs to study combining ability of newly generated maize inbred lines and at the same time to discriminate the inbred lines into heterotic groups. Among the checks, BH-540 and BHQPY-545 are medium maturing single cross hybrids released by Bako National Maize Research Project (BNMRP) for mid to high potential maize growing agro-ecologies of Ethiopia. BH-540 is anormal maize while BHQPY-545 is quality protein maize (QPM) hybrid. Melkassa-2 and Melkassa-6Q are drought stress tolerant and early maturing, respectively, open pollinated varieties (OPVs) released by MARC for drought prone areas of Ethiopia. Melkassa-2 is normal maize while Melkassa-6Q is a QPM OPV. The experiment was planted at MARC in 6x9 alpha-lattice design (Patterson and Williams, 1976) with two replications. Each plot comprised of 4 rows of 5.1 m long with the spacing of 0.75 m between rows and 0.30 m between plants. Two seeds were planted per hill on 26$^{th}$ of June 2010 and later thinned out to one plant per hill after seedlings established well. Diammonium phosphate (DAP) fertilizer was applied at planting at the rate of 100 kg/ha while urea was applied at the rate of 50 kg/ha at knee height stage of the crop. Other cultural practices like weeding and pest management has been done manually throughout the entire growing season as required.

Data were collected on date of emergence: date on which 50% of the seedlings in each plot emerged above the soil surface, stand count after thinning: recorded as the number of plants per plot after thinning, anthesis to silking interval: this was recorded as the difference between anthesis date and silking date, days to maturity: the number of days from planting to when 50% of the kernels on the cob show black layer on the tip of the kernel, biomass yield: the total above ground biological yield (grain and other parts) in tons per hectare obtained from each plot at harvest, number of ears per plant: the total number of harvested ears in each plot divided by the stand count at harvest, number of kernel rows per ear: the total number of kernel rows of the ear was counted from five randomly taken ears and the average value was used as kernel rows per ear, number of kernels per row: this was recorded by counting kernels in each row from five randomly taken ears and the average value was recorded as kernels per row.

Table 1. Descriptions of the lines, testers and checks used in Melkassa in 2010

| Line Code | Pedigree | Stock ID |
|---|---|---|
| L1 | CML505-B | M22-1 |
| L2 | CML509-B | M22-2 |
| L3 | CML507-B | M22-3 |
| L4 | ZEWAc1F2-300-2-2-B-1-B*4-1-B-B | M22-4 |
| L5 | ZEWAc1F2-134-4-1-B-1-B*4-1-B-B | M22-5 |
| L6 | ZEWAc1F2-254-2-1-B-1-BB-1-B-B | M22-6 |
| L7 | ZEWBc1F2-216-2-2-B-2-B*4-1-B-B | M22-7 |
| L8 | MAS[MSR/312]-117-2-2-1-B*3-B | M22-8 |
| L9 | CML442-BB-B | M22-9 |
| L10 | CML444-BB-B | M22-10 |
| L11 | CML443-BB-B | M22-11 |
| L12 | CML395-BB-B | M22-12 |
| L13 | CML488-BB-B | M22-13 |
| L14 | CML489-BB-B | M22-14 |
| L15 | CML440-B | M22-15 |
| L16 | CML445-B | M22-16 |
| L17 | [CML444/CML395//ZM521B-66-4-1-1-1-BB]-3-3-1-1-B-B | M22-17 |
| L18 | [CML312/CML444//[DTP2WC4H255-1-2-2-BB/LATA-F2-138-1-3-1-B]-1-3-2-3-B]-2-1-2-BB-B-B | M22-18 |
| L19 | [CML442/CML197//[TUXPSEQ]C1F2/P49-SR]F2-45-7-3-2-BBB]-2-1-1-1-1-B*4-B | M22-19 |
| L20 | [CML442/CML197//[TUXPSEQ]C1F2/P49-SR]F2-45-7-3-2-BBB]-2-1-1-2-3-B*4-B | M22-20 |
| L21 | Pool15QPMFS57-B-5-B-#-B-B-B-B-B | M22-21 |
| L22 | Pool15QPMFS440-B-4-B-#-B-B-B-B-B | M22-22 |
| L23 | Pool15QPMFS309-B-1-B-B-B-B-B-B | M22-23 |
| L24 | Pool15QPMFS51-B-8-B-B-B-B-B | M22-24 |
| **Testers** | | |
| T1 | CML312/CML442 | Tester A |
| T2 | CML202/CML395 | Tester B |
| **Checks** | | |
| BH-540 | SC-22 x 124b-(113) | Medium maturing normal maize hybrid |
| Melkassa-2 | ZM-521 | Drought tolerant normal maize OPV |
| Melkassa-6Q | Pool15 C7 QPM | Drought tolerant QPM OPV |
| BHQPY-545 | CML161 x CML165 | Medium maturing QPM hybrid |

***Statistical Analysis***

The data collected for all yield and yield-related traits were analysed using PROC MIXED procedure in SAS (SAS, 2004). In the analysis, entries were used as fixed factor while replications and incomplete blocks within replication were considered as random factors. Entry means adjusted for block effects as analyzed according to lattice design (Cochran and Cox, 1957) were used to perform combining ability analysis.

Further analysis was done according to the line x tester analysis to partition the mean square due to crosses into lines, tester and line by tester effects (Dabholkar, 1999, Singh and Chaudary, 1985) using SAS computer program (SAS, 2004) for traits that showed significant differences among crosses. The combining abilities were analyzed, and GCA and SCA effects were estimated accordingly using the formula given in the following section.

## 3. RESULTS AND DISCUSSION

### Mean Square Performance

Analysis of variance showed that mean squares were highly significant for traits such as number of kernel rows per ear, number of ears per plant, number of kernels per row and biomass yield. But non-significant differences were obtained for anthesis-silking interval, date of emergence, stand count after thinning and ear diameter (Table 2). Due to this fact, further genetic analysis and discussions were not done for these traits with non significant genotype mean squares. In line to these findings, significant mean square due to genotypes for grain yield and yield related traits in maize were also reported by previous investigators (Bayisa, 2004; Gudeta, 2007; Akbar, *et al.*, 2009; Rahman, 2010; Shams, 2010). Mean squares due to crosses were highly significant for days to maturity, biomass yield, number of kernels per row, number of rows per ear and number of ears per plant. This indicates that the crosses were sufficiently different from each other for these traits and hence, selection is possible to identify the most desirable crosses. The differences among the checks were not significant for all the traits studied. The current finding is in line with the findings of Legesse *et al.* (2009) and Mosa (2010).

Table 2. Mean squares due to genotypes and errors for grain yield and yield related traits of maize test crosses evaluated at Melkassa in 2010.

| | | Mean squares | | | | |
|---|---|---|---|---|---|---|
| Sources of variation | Df | EPP (No) | NKR (No) | BY (t/ha) | DM (days) | KRE (No) |
| Replication (R) | 1 | 0.001ns | 1.40ns | 6.45ns | 15.64* | 1.64* |
| Incomplete block (blk/R) | 16 | 0.025ns | 9.54ns | 2.22ns | 7.97* | 0.45ns |
| Genotype (G) | 51 | 0.017** | 27.52** | 10.35** | 4.79** | 0.83** |
| Cross (C) | 47 | 0.0168** | 26.06** | 10.81** | 4.08ns | 0.88** |
| Check (Ch) | 3 | 0.017 ns | 36.40 ns | 6.39 ns | 11.83 ns | 0.34 ns |
| Check vs Cross ( Ch vs C) | 1 | 0.025 ns | 69.73 ns | 0.73 ns | 17.33 ns | 0.18 ns |
| Error(E) | 51 | 0.005 | 4.085 | 1.63 | 1.78 | 0.19 |

*and ** = Significant and highly significant, respectively ns= non significant, DM = days to maturity, KRE= number of kernel rows per ear, BY = biomass yield, EPP= number of ears per plant, NKR=number of kernels per row

### *Combining Ability Analysis*

Line GCA mean squares were highly significant for biomass yield, number of kernels per row, number of rows per ear and number of ears per plant (Table 3). For tester GCA, number of kernels per row showed highly significant differences. The non significant difference tester mean square observed for most the traits suggest that the testers used for the current study had comparable potential for the studied traits. In line with the results of this study, Legesse *et al*. (2009) found significant mean squares due to GCA of lines. Mosa (2010) found highly significant mean square due to top crosses entries, checks, line GCA and non-significant mean square due to check vs crosses for most traits he studied.

Table 3. Mean squares for grain yield and yield related traits in 48 test crosses evaluated at Melkassa in 2010

| **Sources of variation** | **Df** | **EPP (No)** | **NKR (No)** | **BY (t/ha)** | **DM (days)** | KRE (No) |
|---|---|---|---|---|---|---|
| Line (GCAf) | 23 | 0.0252** | 24.91** | 12.59** | 4.88ns | 1.32** |
| Tester (GCAm) | 1 | 0.00075ns | 28.83** | 1.32ns | 0.33 ns | 0.25 ns |
| Line x Tester (SCAfm) | 23 | 0.0091 ** | 27.08** | 9.43** | 3.43ns | 0.46** |
| Error (E) | 47 | 0.0057 | 4.49 | 1.75 | 1.89 | 0.12 |

*and ** = Significant and highly significant, respectively, DM = days to maturity, KRE= number of kernel rows per ear and BY = biomass yield, EPP= number of ears per plant, NKR=number of kernels per row.

Analysis of variance for SCA also showed highly significant differences for biomass yield, number of ears per plant, number of kernels per row and number of rows per ear (Table 3). In conformity to this result, several findings have been reported by earlier investigators (Ahmad and Saleem, 2003; Bayisa *et al.,* 2008). This indicates importance of non additive gene action in controlling the traits under consideration.

### Estimates of general combining ability effects

For total biomass yield, lines L1, L7, L14 and L19, showed positive and significant GCA effects while lines L3, L15, L17, L18, L21 and L24 showed negative and significant GCA effects (Table 4). For this trait, L14 and L18 were the best and poorest general combiners, respectively. In line with the current findings Bayisa (2004), Koppad (2007) and Wali *et al.* (2010) reported considerable amount of significant positive and negative GCA effects for biomass yield in their study on maize.

With respect to number of rows per ear, L7 and L23 showed positive and significant GCA effects, whereas L11 showed significant negative GCA effect (Table 4). The positive GCA effect is desired for number of rows per ear as it is the most important yield component that directly contributes to increased grain yield. Hence, inbred lines with high GCA effects for this trait can be suitable parents for hybrid formation as well as for inclusion in future breeding programs. Such parents contribute favorable alleles in the process of synthesis of new varieties.

The result of this study is in conformity with the findings of Asif *et al*. (2007) and Habtamu and Hadji (2010).
L20 had positive and significant GCA effects for number of ears per plant while L12 had negative and significant GCA effects (Table 4). The positive and significant GCA effects for number of ears per plant indicates prolificacy which is desirable in increasing maize productivity while negative and significant GCA effects for the same trait indicates non-prolificacy which is undesirable. Hence, inbred lines with positive and significant GCA effect could be selected for further use in the breeding program. Similar findings were previously reports by Bayisa (2004) Gudeta (2007) in line x tester study of maize inbred lines.
For number of kernels per row, lines L2, L4, L5, L6, L8, and L14 manifested positive and significant estimates of GCA effects, while inbred lines L9, L 10, L20, L21 and L24 exhibited negative and significant GCA effects (Table 4). The positive GCA effect indicates good general combination for this trait. The current results are in agreement with the finding of Dagne, (2002), Asif *et al*. (2007) and Habtamu and Hadji (2010).
Table 4. Estimates of general combining ability effects for grain yield and yield related traits of maize inbred lines studied in line x tester crosses at Melkassa in 2010

| Line | RPE | EPP | NKR | BY |
|---|---|---|---|---|
| L1 | 0.39 | 0.013 | -1.72 | 6.06** |
| L2 | 0.24 | -0.008 | 3.28** | 0.68 |
| L3 | -0.13 | -0.078* | 0.03 | -2.22** |
| L4 | -0.11 | -0.023 | 3.03** | -0.53 |
| L5 | -0.91 | 0.033 | 6.28** | -0.96 |
| L6 | -0.26 | -0.068 | 4.53** | 1.24 |
| L7 | 2.74** | -0.073 | 1.03 | 2.74** |
| L8 | -0.26 | -0.053 | 4.78** | -0.91 |
| L9 | -0.06 | -0.008 | -5.97** | -0.07 |
| L10 | 0.34 | -0.003 | 0.03 | -0.97 |
| L11 | -1.16* | 0.133** | -3.37** | 0.75 |
| L12 | 0.34 | -0.178** | -1.22 | -0.36 |
| L13 | -0.41 | 0.168** | -0.47 | -0.61 |
| L14 | -0.36 | 0.033 | 4.03** | 6.97** |
| L15 | 0.54 | -0.113** | 1.08 | -3.37** |
| L16 | 0.04 | -0.085* | -1.87 | -0.01 |
| L17 | -0.81 | -0.105* | 0.78 | -2.93** |
| L18 | 0.04 | -0.108* | 0.03 | -3.43** |
| L19 | -0.71 | 0.108** | 0.58 | 1.36* |
| L20 | -0.36 | 0.263** | -3.72** | -0.65 |
| L21 | -0.31 | -0.138** | -6.72** | -1.97** |
| L22 | -0.31 | 0.113** | -0.72 | -0.32 |
| L23 | 1.64** | -0.018 | 2.78* | 0.98 |
| L24 | -0.11 | 0.193** | -6.47** | -1.45* |
| **SE line** | **0.23** | **0.038** | **1.06** | **0.66** |
| **SE (gi-gj) line** | **0.32** | **0.05** | **1.50** | **0.94** |

* and** = significant and highly significant, respectively, , BY= biomass yield, DM= number of days to maturity, EPP= number of ears per plant, NKR=number of kernels per row, NRE = number of kernel rows per ear,

**Estimation of specific combining ability**

Estimates of SCA effects for biomass yield revealed that 20 crosses manifested significant SCA effects (Table 5). For this trait crosses with positive and significant SCA effects are desirable as they had increased level of biomass yield. Hence, crosses L6 x T1, L11 x T2 and L16 x T1were the better specific combiners, whereas L6 x T2, L11 x T1 and L16 x T2 were the poorest specific combiners. In agreement with the results of this study, Koppad (2007) observed both positive and negative, and significant estimates of SCA effects for this trait, whereas Bayisa (2004) found non- significant SCA effects on study of heterosis and combining ability in maize inbred lines.

Only six crosses were found to exhibit significant level of SCA effects for number of rows per ear (Table 5). This shows that most of the crosses evaluated in the current study did not significantly deviate from what would have been predicted based on their parental performance. Crosses L14 x T1, L20 x T2 were the best specific combiners while L12 x T2 and L14 x T2, L20 x T1 and L12 x T1 worst specific combiners for this trait, respectively (Table 5). This result is in conformity with findings of Shashidhara (2008).

The results of estimates of SCA effect for number of kernels per row showed that 22 crosses evaluated in the current study had significant SCA effects (Table 5). Crosses L21 x T2, L24 x T2 and L19 x T1 and were the best specific combiners while L21 x T1, L24 x T1 and L19 x T2 were poor specific combiners indicating significant deviation of these crosses from that has been expected based on mean performance of the parents.

Positive SCA effects are desirable for this trait as it can contribute to grain yield in maize. Similar results have previously been reported by Asif *et al*. (2007) and Habtamu and Hadji (2010).

For number of ears per plant, crosses L13 x T2 and L22 x T1 and L13 x T1 L22 x T2 were the best and poorest specific combiners, respectively (Table 5). Bayisa (2004) and Gudeta (2007) in their study on line x tester analysis in maize found only few desirable cross combinations with increased number of ears per plant.

Table 5. Estimates of specific combining ability effects of line x tester crosses evaluated for grain yield and yield related traits at Melkassa in 2010.

| Crosses | RPE | EPP | NKR | BY |
|---|---|---|---|---|
| L1 x T1 | -0.42 | -0.011 | -4.98** | -1.10 |
| L1 xT2 | 0.42 | 0.011 | 4.98** | 1.10 |
| L2 xT1 | 0.43 | -0.061 | -0.48 | 0.11 |
| L2 x T2 | -0.43 | 0.061 | 0.48 | -0.11 |
| L3 x T1 | 0.25 | -0.041 | 1.28 | -2.31* |
| L3 x T2 | -0.25 | 0.041 | -1.28 | 2.31* |
| L4 x T1 | 0.08 | -0.006 | -0.73 | 0.02 |
| L4 x T2 | -0.08 | 0.006 | 0.73 | -0.02 |
| L5 x T1 | 0.18 | -0.081 | -1.98 | -0.11 |
| L5 x T2 | -0.18 | 0.081 | 1.98 | 0.11 |
| L6 x T1 | -0.27 | 0.089 | 1.78 | 5.04** |
| L6 x T2 | 0.27 | -0.089 | -1.78 | -5.04** |
| L7 x T1 | 0.53 | 0.034 | 3.28* | -2.02* |
| L7 x T2 | -0.53 | -0.034 | -3.28* | 2.02* |
| L8 x T1 | -0.07 | 0.024 | 0.53 | 1.05 |
| L8 x T2 | 0.07 | -0.024 | -0.53 | -1.05 |
| L9 x T1 | -0.87 | -0.001 | -3.23* | -1.88 |
| L9 x T2 | 0.87 | 0.001 | 3.23* | 1.88 |
| L10 x T1 | -0.07 | 0.014 | 0.28 | -0.11 |
| L10 x T2 | 0.07 | -0.014 | -0.28 | 0.11 |
| L11 x T1 | -0.57 | 0.079 | -2.63 | -3.45** |
| L11 x T2 | 0.57 | -0.079 | 2.63 | 3.45** |
| L12 x T1 | -0.67* | -0.061 | 3.53* | -0.28 |
| L12 x T2 | 0.67* | 0.061 | -3.53* | 0.28 |
| L13 x T1 | 0.28 | -0.176** | -4.73** | 1.90* |
| L13 x T2 | -0.28 | 0.176** | 4.73** | -1.90* |
| L14 x T1 | 1.03** | -0.021 | 0.78 | 2.36* |
| L14 x T2 | -1.03** | 0.021 | -0.78 | -2.36* |
| L15 x T1 | 0.13 | 0.034 | 2.23 | -2.86* |
| L15x T2 | -0.13 | -0.034 | -2.23 | 2.86* |
| L16 x T1 | 0.03 | -0.044 | 4.58** | 4.57** |
| L16 x T2 | -0.03 | 0.044 | -4.58** | -4.57** |
| L17 x T1 | -0.42 | 0.091 | 4.03* | 2.27* |
| L17 x T2 | 0.42 | -0.091 | -4.03* | -2.27* |
| L18 x T1 | 0.03 | 0.019 | 1.78 | -0.09 |
| L18 x T2 | -0.03 | -0.019 | -1.78 | 0.09 |
| L19 xT1 | 0.43 | 0.054 | 4.83** | -0.78 |
| L19 x T2 | -0.43 | -0.054 | -4.83** | 0.78 |
| L20 x T1 | -0.97** | 0.019 | 4.03* | -0.75 |
| L20 x T2 | 0.97** | -0.019 | -4.03* | 0.75 |
| L21 x T1 | -0.02 | -0.081 | -7.98** | 1.84 |
| L21 x T2 | 0.02 | 0.081 | 7.98** | -1.84 |
| L22 x T1 | 0.38 | 0.139* | 3.03 | 0.15 |
| L22 x T2 | -0.38 | -0.139* | -3.03 | -0.15 |
| L23 x T1 | 0.63 | -0.001 | -1.98 | -2.65** |
| L23 x T 2 | -0.63 | 0.001 | 1.98 | 2.65** |
| L24 x T1 | -0.02 | -0.011 | -7.23** | -0.93 |
| L24 x T2 | 0.02 | 0.011 | 7.23** | 0.93 |
| **SE SCA** | **0.324** | **0.053** | **1.49** | **0.34** |
| **SE (Sji-Skl)** | **0.46** | **0.075** | **2.12** | **1.32** |

* and** = significant and highly significant, respectively, BY = biomass yield, EH = ear height, EPP= number of ears per plant, NKR number of kernels per row, RPE = number of rows per ear

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