**Combining Ability of Maize (*Zea Mays* L.) Inbred Lines** **for** **Grain Yield and Related Traits In western Amhara Region, Ethiopia**

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**ABSTRACT**

Information on combining ability and heterotic grouping for newly developed inbred lines is paramount importance to design future breeding strategies for the development of hybrid varieties. The objectives of the present study were to identify inbred lines that have good performance in general combining ability, to determine heterotic group and to select high yielding and diseases tolerance three way cross hybrids. Ninety four crosses (forty seven inbred lines each crossed with two testers) along with three standard checks (BH 661, BH 546 and AMH 851) were evaluated in alpha lattice design with three replications during 2019 cropping season. Except corn rust most parameters showed significant differences at (P ≤ 0.01) significant level whereas grey leaf spot showed significant differences at (P ≤ 0.05) significant level. Three hybrids were high yielding and better performance in grain yield compared to standard checks. Out of all inbred lines, ten inbred lines were best general combiner for grain yield. Forty four three way crosses were best specific combiners for grain yield. 26 inbred lines were grouped in heterotic group A while the remaining inbred lines were grouped into heterotic group B.

**Key words:** General combining ability, Inbred line, Line x Tester, Maizeand Specificcombining ability

**INTRODUCTION**

Maize (*Zea mays* L.) is one of the worlds’ three primary cereal crops. Maize holds a unique position in world agriculture as a food, feed and as a source of industrially important products. It accounts for 15-56% of the total daily calories of people in developing countries, and is currently produced on nearly 100 million hectares in 125 developing countries and is among the three most widely grown crops in 75 of those countries (FAOSTAT, 2010). It is an important grain crop of the world and it ranks third, after wheat and rice in area coverage and total production (Mosisa Worku *et a*l., 2001). According to World Food and Agriculture organization (FAO) (2019), 197 million hectare of land was covered by maize and produced 1,134 million tons of maize grain in 2017 production season.

In Ethiopia, among all cereals, maize is second to tef (*Eragrostis tef* L.) in area coverage (2.30 million hectare) but first in productivity and total production (96.4 million quintals) (CSA, 2020). The current national productivity average per hectare (4.24 tons ha-1) (CSA, 2020) is considerably low as compared to developed countries. The national average grain yield per hectare of some of the countries, for example, is 10.68, 10.73, 9.36, 5.18, and 6.0 tons ha-1 in that order for USA, Canada, Germany, Brazil and China (FAOSTAT, 2015). Maize production can be increased by developing high yielding and disease resistant varieties. The hybrid development in Ethiopia has been highly effective in increasing maize yields since the commercialization of the hybrids in the country. Development of hybrid maize varieties needs selection of appropriate parents (inbred lines) which is secret of success in hybrid maize variety development (Hallauer and Miranda, 1988).

Information on the combining ability of parental inbred lines is very important for determining breeding strategies, classifying the parental inbred lines, defining heterotic groups, and predicting future hybrid performance (Beyene Legesse *et al*., 2009). Classifying inbred lines into heterotic groups is critical to determine the potential usefulness of the inbred lines for the development of high yielding hybrids and synthetic varieties. Therefore, knowledge on the heterotic groups of inbred lines is important before they can be deployed in variety development. The term heterotic group refers to a group of related or unrelated genotypes from the same or different populations, which display similar combining ability and heterotic response when crossed with genotypes from other genetically distinct germplasm groups (Melchinger and Gumber, 1998).

Combining ability studies provide good information on the genetic mechanisms controlling the inheritance of quantitative traits that can be exploited in breeding and enable the breeders to select suitable parents for further improvement or use in hybrid breeding for commercial purposes. In order to implement effective hybrid breeding program, information on the combining ability of inbred lines is crucial. Combining ability refers to the capacity or ability of a genotype to transmit superior performance to its crosses; it has two components, general and specific combining abilities. General combining ability refers to the average performance of the genotype in a series of hybrid combinations whereas specific combining ability is the performance of a parent in specific cross in relation to general combining ability (Hallauer and Miranda, 1988). Combining ability analysis is one of the powerful tools identifying better combining pre-breeding materials which may be hybridized to exploit heterosis and select better crosses for improvement. The line × tester analysis method which was suggested by Kempthorne (1957) is one of the powerful tools available to estimate general and specific combining ability effects and aids in selecting desirable parents and crosses.

The Ethiopian maize improvement program has implemented decentralized breeding approach in which different research centers are representing different agro ecology of the country and are developing inbred lines that are adaptable and high yielding to those agro ecologies. A large number of elite maize inbred lines and F1s hybrids were developed by the Ethiopian maize improvement program. Currently, these are available at different centers such as Bako, Ambo, Melkasa, Holetta, Kulumsa, Jimma and Adet Agricultural Research Centers. To enhance hybrid formation and open pollinated variety development information on the combining abilities and heterotic group of inbred lines are extremely important. It is always mandatory for any breeding program to generate such information for any new batch of inbred lines generated. However, there is little or no information on the combining ability and hetrotic group of forty seven inbred lines. In the current study, therefore, an attempt was made to generate information on 47 elite maize inbred lines crossed to two testers in line x tester mating design and the main objective was to identify inbred lines that have good performance in general combining ability, to determine heterotic group and to select high yielding and diseases tolerance three way cross hybrids.

**MATERIALS AND METHODS**

**Description of the Study Area**

The study was conducted in 2019 main cropping seasons in Yilmana Densa, Ayehu Guagusa, Jabitehinan and Hulet Eju Enes districts. Yilmana Densa is located at 11°16' N and 37°29' E with an altitude of 2240 m.a.s.l. Its annual average rain fall is 1432 mm and the temperature ranges from 10.8°c to 25.5°c. Ayehu Guagusa is located at 10°76' N and 36°81' E with an altitude of 2073 m.a.s.l. Its annual average rain fall is 1200 mm and the temperature ranges from 12.5°c to 25°c. Jabitehinan is located at 10°69' N and 37°26' E with an altitude of 1820 m.a.s.l. Its annual average rain fall is 884 mm and the temperature ranges from 12.6°c to 28.4°c. Hulet Eju Enes is located at 11°20' N and 37°88' E with an altitude of 2470 m.a.s.l. Its annual average rain fall is 1334 mm and the temperature ranges from 10.5°c to 23.84°c and the soil type of all sites is classified as Nitosol.

**Planting Materials**

 94 three way crosses and 3 standard checks (BH-661, AMH-851, and BH-546) were evaluated. 48 crosses were conducted at Yilmana Densa, Ayehu Guagusa, Jabitehinan whereas 46 crosses were conducted at Yilmana Densa, Ayehu Guagusa, and Hulet Eju Enes districts (Appendix Table1). The 94 three way crosses developed using 47 new inbred lines (as male parents) and two single cross testers (CML-395/CML-202 and CML-312/CML-442) (as female parents) using line by tester mating design in 2018 main cropping season. Testers used in this study were identified by CIMMYT and widely used to study combining ability of newly generated maize inbred lines. Testers are also used to group inbred lines into different heterotic groups that can finally be utilized in breeding.

**Trail Management**

The experiments were planted in alpha-lattice design with three replications. Each plot comprises 1 row of 5.25 m long with the spacing of 0.75 m between rows and 0.25 m between plants (21 plants per plot). Two seeds per hill were planted and later thinned out to one plant per hill after seedlings established well. NPS fertilizer was applied at planting at the rate of 200 kg/ha while urea was applied at the rate of 200 kg/ha. All NPS was applied fully at time of planting and Urea was applied using split application one-third at the time of planting and the remaining two-third was applied at knee height stage of the crop. All other agronomic practices were done as per the recommendation throughout the entire growing season as required.

**Data Collection and Analysis**

Data were recorded on five randomly selected plants for plant height and ear height through a plot based for days to 50% anthesis, days to 50% silking, days to maturity, grain yield, plant aspect, ear aspect and severity of each disease (late blight, grey leaf spot and rust) were scored. All of data taken were subjected for analysis of variance using PROC GLM procedure in SAS software version 9.2. The mean squares from line x tester mating design and the GCA and specific combing ability (SCA) effects were calculated according to the procedures developed by Kempthorne (1957) and adopted by Singh and Chaudhary (1985) and Dabholkar (1999). The significance of GCA and SCA effects were tested using t test. Heterotic grouping was determined according to the CIMMYT heterotic classification system as A, B and AB. Depending on the direction of the SCA estimates such that lines displaying positive SCA with tester A were grouped towards the opposite heterotic group, and vice versa, whereas lines exhibiting positive SCA to both testers were grouped under AB heterotic group (Vasal *et al*., 1992).

**RESULTS AND DISCUSSION**

The combined analysis of variance showed that most of the traits were significantly different (p<0.01) whereas grey leaf spot showed significant differences at (P ≤ 0.05) significant level (Appendix Table 2 and 3). However, corn rust was not significantly different (Appendix Table 2). Significant difference among the genotypes for days to anthesis, days to silking, days to maturity, plant height, ear height, gery leaf spot, Turcicum leaf blight, ear aspect, plant aspect and grain yield indicates the presence of genetic variation among the genotypes for further improvement of the traits and hence, selection is possible to identify the most desirable crosses.

Three way cross hybrid 43 (CML-395/CML-202//633321) (9257.2 kgha−1) had better performance in grain yield compared to the standard cheek AMH-851 (8889.7 kgha−1) (Appendix Table 2). Three-way cross hybrid 5 (CML-395/CML-202//421412) produced the highest grain yield (9498.3 kgha−1) followed by three-way crosses hybrid 13 (CML-395/CML-202//545342) (9097.9 kgha−1) with over all mean value of 7094.1 kgha−1 (Appendix Table 3). This three way cross had better performance in grain yield compared to standard cheek BH 546 (8612.9 kgha−1), AMH-851 (7910.2 kgha−1) and BH-661 (9066.5kgha−1). Similar result was reported by Abenezer Abebe *et al*. (2020) in their combining ability and heterosis analysis of maize inbred lines.

**Combining Ability Effect**

Developing high yielding hybrids depend on careful choice of parents. Information regarding general and specific combining ability is very important to select desirable parents and crosses. The female parent of L12 was the best general combiner for days to anthesis, days to silking and days to maturity with negative and significant GCA effect. Lines that show negative GCA effect indicates contribute to early maturity as they showed the tendency of early flowering and important to escape late coming disease and pest infestation as well as terminal moisture stress (Table 4). L19 and L11 also showed high negative GCA effects and early maturing lines (Table 1). The result of the current study was in accordance with the findings of Dufera Tulu (2017), Gudeta Nepir (2007), Shushay Welderufael (2014) and Ziggiju Mesenbet *et al.* (2016) who reported significant positive and negative GCA effects for anthesis and silking.

Inbred lines L20, L14 and L10 contributed high negative and significant GCA effects for plant and ear height indicating that these lines significantly contributed to reduce plant stature and can be utilized for developing short hybrids to minimize yield loss due to root and stem lodging. L13, L18, L12 and L8 recorded high positive significant GCA effects for plant height and ear height indicating that these lines contributed to taller plant stature in their crosses and were good general combiners for tallness (Table 1). Inbred lines L6, and L13 also exhibited high negative and significant GCA effects whereas L1, L2, L5, L16 and L19 showed high positive and significant GCA effects for plant and ear height (Table 4). In line with the present study Dagne Wegary *et al.* (2010), Shushay Welderufael (2014) and Ziggiju Mesenbet *et al.* (2016) found significant positive and negative GCA effects for plant height.

GCA for grain yield exhibited ten inbred lines (L2, L3, L4, L6, L9, L13, L17, L20, L22 and L24) had high significant positive effects (Table 1 and 4). These lines were best general combiner for grain yield and can be used for development of high yielding hybrids by contributing desirable alleles. Positive significant GCA effects for maize lines indicated that they are desirable parent for maize hybrid development and involvement in the maize breeding program as they can be good allele source in the process of varietal development. L15 and L2 was the poorest general combiner for grain yield with significant and negative GCA effect signifying that those lines were undesirable combiner for developing high yielding hybrids (Table 1 and 4). Alamerew Sentayehu and Warsi (2015), Bitew Tilahun (2016), Worknesh Terefe (2016), Abiy Balcha (2017) and Dufera Tulu (2017) identified inbred lines with positive significant and lines with significant negative GCA effects for grain yield in their studies.

Significant SCA showed comparative importance of interactions in determining the performance of produced hybrids. SCA effect analysis revealed that 44 three-way crosses had significant positive SCA effects for grain yield (Table 2 and 5). Other 44 crosses also expressed significant negative SCA effects and the remaining 6 crosses showed non significant effect in both directions for the same trait. Positive SCA effects resulted from crossing of lines from different heterotic group but negative SCA effects due to crossing of lines from the same heterotic group.

Positive significant SCA effects indicated that produced hybrids were good specific combiners for developing high-yielding hybrids. Three way crosses hybrids 5, 13 and 43 provided high mean grain yield and possessed desirable significant high SCA effects, revealing good correspondence between mean grain yield and SCA effects. This result is in line with the previous finding of Amare Seyoum *et al.* (2016), Abiy Balcha (2017) and Berhanu Tadesse (2009) who reported significant SCA effect among hybrids for grain yield.

**Heterotic Grouping**

Inbred lines heterotic groups could be identified based on the value of SCA effects for grain yield. Three hetrotic groups were identified depending on the direction of the SCA estimates. Lines displaying positive SCA effects with a tester were grouped toward the opposite heterotic group, whereas lines exhibiting positive SCA effects to both testers were grouped toward both groups, and lines that expressed negative SCA effects with the two testers could be discarded (Vasal *et al*., 1992).

Kanyamasoro *et al.* (2012) explained that positive SCA effects indicates that inbred lines are in different heterotic group, whereas negative SCA effect indicates genetic similarity of the parents. The result in this study exhibited that 52 hybrid combination revealed positive SCA effect for grain yield with tester 1 (CML395/CML202) and the remaining 42 hybrid combination showed negative SCA effect for grain yield with the same tester and vice versa with tester 2 (CML442/CML312) indicated 26 inbred lines were grouped in heterotic group “A” and the remaining 21 lines were classified in heterotic group “B” (Table 3 and 6). Maximum genetic variability and hybrid vigor (heterosis) can be exploited by crossing lines from different heterotic groups. Girma Chemada *et al.* (2015) and Dufera Tulu (2017) classified lines into different heterotic groups using the direction of SCA effects for grain yield.

Table 1: Combined General combining ability of 24 lines and two tester for yield and yield related traits at Yilmana Densa, Ayehu Guagusa and Jabitehinan

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Line  | Pedigree | DA | DS  | DM | PH | EH | GY |
| 1 | 125433  | 0.06 | -0.09 | 0.12 | 2.08 | -0.30 | -9.91\*\* |
| 2 |  125511  | 2.06 | 1.97 | 0.67 | -0.64 | -4.30\* | 333.63\*\* |
| 3 | 125741  | -0.05 | 0.02 | -0.60 | 1.03 | -7.57\*\* | -583.48\*\* |
| 4 | 137121  | 0.84 | 0.74 | 0.62 | 0.97 | 2.26 | -91.18\*\* |
| 5 | 215111  | -0.78 | -0.53 | -0.72 | 5.31\*\* | -1.41 | 6.84\*\* |
| 6 | 215321  | 0.00 | -0.09 | -0.05 | 2.81\* | 0.87 | 332.58\*\* |
| 7 | 215411 | -2.11 | -0.98 | -0.44 | -2.03 | 0.20 | -367.32\*\* |
| 8 | 441221 | -0.94 | -0.81 | 0.06 | 11.81\*\* | 8.54\*\* | -52.25\*\* |
| 9 | 421521 | -0.16 | 0.08 | 0.67 | 3.81\* | 7.93\*\* | 590.03\*\* |
| 10 | 527131  | -1.83 | -1.65 | -0.72 | -7.64\*\* | -9.69\*\* | -958.85\*\* |
| 11 | 545411  | -0.11 | -0.31 | -1.60 | -1.69 | -0.69 | -810.06\*\* |
| 12 | 125441 | 2.56\* | 2.47\* | 0.06 | 8.86\*\* | 8.09\*\* | 78.78\*\* |
| 13 | 442232 | -0.39 | -0.42 | 0.01 | 8.53\*\* | 11.59\*\* | 411.76\*\* |
| 14 | 545341  | -0.61 | -0.65 | -0.60 | -11.64\*\* | -9.63\*\* | -26.05\*\* |
| 15 | 545311 | 0.39 | 0.02 | -0.27 | -4.53\*\* | -1.46 | -997.16\*\* |
| 16 | 125442 | 1.11 | 1.19 | 0.45 | 5.69\*\* | 5.15\*\* | -305.78\*\* |
| 17 | 125432 | 1.17 | 1.30 | 1.23 | 4.25\* | 6.09\*\* | 656.10\*\* |
| 18 | 442231  | 2.45 | 1.97 | 1.06 | 8.64\*\* | 11.70\*\* | 71.55\*\* |
| 19 | 163421 | -0.66 | -0.98 | -0.83 | -5.36\*\* | -4.69\*\* | -291.34\*\* |
| 20 | 125431  | -0.39 | -0.53 | -0.22 | -12.42\*\* | -11.69\*\* | 555.56\*\* |
| 21 | 633152  | -0.39 | -0.65 | 0.62 | -9.19\*\* | -6.41\*\* | -33.84\*\* |
| 22 | 633321 | -0.11 | 0.02 | 0.34 | 7.03\*\* | 4.15\* | 841.85\*\* |
| 23 | 421411 | -1.28 | -1.42 | -0.33 | -5.36\*\* | -2.35 | 167.51\*\* |
| 24 | 563121  | -0.83 | -0.65 | 0.45 | -10.31\*\* | -6.41\*\* | 481.03\*\* |
| Testers  |
| 1 | CML 395/CML202 | 0.05 | 0.13 | 0.58 | 2.33 | 3.76 | 640.12\*\* |
| 2 | CML-442/CML-312 | -0.05 | -0.13 | -0.58 | -2.33 | -3.76 | -640.12\*\* |

Table 2: Combined Specific combining ability of 48 three way crosses for yield and yield related traits at Yilmana Densa, Ayehu Guagusa and Jabitehinan

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Line | Tester | DA | DS  | DM | PH | EH | GY |
| 1 | 1 | 0.17 | 0.37 | -0.08 | -8.33 | -3.43 | -802.15\*\* |
| 1 | 2 | -0.17 | -0.37 | 0.08 | 8.33 | 3.43 | 802.15\*\* |
| 2 | 1 | -0.28 | -0.35 | -0.08 | 1.28 | -0.21 | 201.13\*\* |
| 2 | 2 | 0.28 | 0.35 | 0.08 | -1.28 | 0.21 | -201.13\*\* |
| 3 | 1 | -0.05 | -0.18 | -0.25 | 0.95 | -2.04 | 575.73\*\* |
| 3 | 2 | 0.05 | 0.18 | 0.25 | -0.95 | 2.04 | -575.73\*\* |
| 4 | 1 | 0.17 | -0.02 | -0.03 | -6.88 | 0.01 | -247.72\*\* |
| 4 | 2 | -0.17 | 0.02 | 0.03 | 6.88 | -0.01 | 247.72\*\* |
| 5 | 1 | 0.00 | 0.04 | -0.36 | -5.77 | -0.65 | 333.63\*\* |
| 5 | 2 | 0.00 | -0.04 | 0.36 | 5.77 | 0.65 | -333.63\*\* |
| 6 | 1 | -0.33 | -0.52 | -0.25 | -2.61 | -0.82 | -365.04\*\* |
| 6 | 2 | 0.33 | 0.52 | 0.25 | 2.61 | 0.82 | 365.04\*\* |
| 7 | 1 | -1.89 | -0.29 | -0.08 | -0.44 | -2.60 | 156.99\*\* |
| 7 | 2 | 1.89 | 0.29 | 0.08 | 0.44 | 2.60 | -156.99\*\* |
| 8 | 1 | 0.50 | 0.54 | 0.64 | 8.62 | 6.40 | 335.75\*\* |
| 8 | 2 | -0.50 | -0.54 | -0.64 | -8.62 | -6.40 | -335.75\*\* |
| 9 | 1 | 0.17 | 0.21 | 0.03 | 0.62 | -0.43 | -1.06 |
| 9 | 2 | -0.17 | -0.21 | -0.03 | -0.62 | 0.43 | 1.06 |
| 10 | 1 | -0.28 | -0.07 | -0.14 | -9.16 | -5.04 | -740.43\*\* |
| 10 | 2 | 0.28 | 0.07 | 0.14 | 9.16 | 5.04 | 740.43\*\* |
| 11 | 1 | 0.00 | -0.07 | -0.03 | -4.33 | -0.71 | -564.07\*\* |
| 11 | 2 | 0.00 | 0.07 | 0.03 | 4.33 | 0.71 | 564.07\*\* |
| 12 | 1 | 0.22 | 0.26 | 0.31 | 0.00 | -0.38 | 335.27\*\* |
| 12 | 2 | -0.22 | -0.26 | -0.31 | 0.00 | 0.38 | -335.27\*\* |
| 13 | 1 | -0.50 | -0.52 | 0.03 | -1.11 | 0.13 | -357.74\*\* |
| 13 | 2 | 0.50 | 0.52 | -0.03 | 1.11 | -0.13 | 357.74\*\* |
| 14 | 1 | -0.50 | -0.85 | 0.31 | 5.73 | 0.79 | 248.29\*\* |
| 14 | 2 | 0.50 | 0.85 | -0.31 | -5.73 | -0.79 | -248.29\*\* |
| 15 | 1 | -0.28 | -0.29 | -0.25 | 2.17 | 2.40 | 169.47\*\* |
| 15 | 2 | 0.28 | 0.29 | 0.25 | -2.17 | -2.40 | -169.47\*\* |
| 16 | 1 | 0.45 | 0.54 | 0.25 | 2.39 | 0.35 | 431.54\*\* |
| 16 | 2 | -0.45 | -0.54 | -0.25 | -2.39 | -0.35 | -431.54\*\* |
| 17 | 1 | 0.72 | 0.65 | -0.08 | 4.50 | 3.07 | -85.22\*\* |
| 17 | 2 | -0.72 | -0.65 | 0.08 | -4.50 | -3.07 | 85.22\*\* |
| 18 | 1 | 1.45 | 0.54 | 0.09 | 3.89 | 0.68 | -594.95\*\* |
| 18 | 2 | -1.45 | -0.54 | -0.09 | -3.89 | -0.68 | 594.95\*\* |
| 19 | 1 | 0.34 | 0.26 | -0.36 | -12.00\* | -1.60 | -373.22\*\* |
| 19 | 2 | -0.34 | -0.26 | 0.36 | 12.00\* | 1.60 | 373.22\*\* |
| 20 | 1 | 0.28 | -0.07 | 0.03 | 3.62 | -3.04 | 3.81 |
| 20 | 2 | -0.28 | 0.07 | -0.03 | -3.62 | 3.04 | -3.81 |
| 21 | 1 | 0.06 | 0.26 | -0.25 | 2.73 | 1.24 | 757.61\*\* |
| 21 | 2 | -0.06 | -0.26 | 0.25 | -2.73 | -1.24 | -757.61\*\* |
| 22 | 1 | -0.11 | -0.18 | 0.70 | 11.73\* | 10.01\* | 558.63\*\* |
| 22 | 2 | 0.11 | 0.18 | -0.70 | -11.73\* | -10.01\* | -558.63\*\* |
| 23 | 1 | 0.39 | 0.37 | -0.08 | 1.67 | 0.07 | 29.19\*\* |
| 23 | 2 | -0.39 | -0.37 | 0.08 | -1.67 | -0.07 | -29.19\*\* |
| 24 | 1 | -0.72 | -0.63 | -0.08 | 0.73 | -4.21 | -5.42 |
| 24 | 2 | 0.72 | 0.63 | 0.08 | -0.73 | 4.21 | 5.42 |

\*= significant at 0.05 probability level, \*\* =significant at 0.01 probability level

 DA = days to anthesis (days), DS = days to silking (days), DM = days to maturity, PH = plant height (cm), EH = ear height (cm) and GY = grain yield (kg/ha).

Table 3: Heterotic grouping based on specific combining ability of grain yield for experiment

|  |  |  |  |
| --- | --- | --- | --- |
| Line | CML395/CML202 (Tester-1)(HB) | CML442/CML312 (Tester-2)(HA) |  |
| SCA of grain yield | SCA of grain yield | Heterotic grouping |
| 1 | -802.15\*\* | 802.15\*\* | B |
| 2 | 201.13\*\* | -201.13\*\* | A |
| 3 | 575.73\*\* | -575.73\*\* | A |
| 4 | -247.72\*\* | 247.72\*\* | B |
| 5 | 333.63\*\* | -333.63\*\* | A |
| 6 | -365.04\*\* | 365.04\*\* | B |
| 7 | 156.99\*\* | -156.99\*\* | A |
| 8 | 335.75\*\* | -335.75\*\* | A |
| 9 | -1.06 | 1.06 | B |
| 10 | -740.43\*\* | 740.43\*\* | B |
| 11 | -564.07\*\* | 564.07\*\* | B |
| 12 | 335.27\*\* | -335.27\*\* | A |
| 13 | -357.74\*\* | 357.74\*\* | B |
| 14 | 248.29\*\* | -248.29\*\* | A |
| 15 | 169.47\*\* | -169.47\*\* | A |
| 16 | 431.54\*\* | -431.54\*\* | A |
| 17 | -85.22\*\* | 85.22\*\* | B |
| 18 | -594.95\*\* | 594.95\*\* | B |
| 19 | -373.22\*\* | 373.22\*\* | B |
| 20 | 3.81 | -3.81 | A |
| 21 | 757.61\*\* | -757.61\*\* | A |
| 22 | 558.63\*\* | -558.63\*\* | A |
| 23 | 29.19\*\* | -29.19\*\* | A |
| 24 | -5.42 | 5.42 | B |

Table 4: Combined General combining ability of 23 lines and two tester for yield and yield related traits at Yilmana Densa, Ayehu Guagusa and Hulet Eju Enese

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Line  | Pedigree | DA | DS  | DM | PH | EH | GY |
| 1 | 441311 | 1.01 | 1.07 | 1.29 | 19.48\*\* | 10.07\*\* | -85.20\*\* |
| 2 | 363122 | 1.4 | 1.41 | -0.88 | 15.37\*\* | 10.68\*\* | -1065.11\*\* |
| 3 | 421412 | -0.38 | -0.48 | -0.54 | 2.76\* | 5.73\*\* | 689.69\*\* |
| 4 | 421211 | 0.01 | 0.13 | 0.62 | 2.87\* | 9.35\*\* | 685.55\*\* |
| 5 | 344311 | 1.4 | 1.85 | 1.01 | 37.48\*\* | 27.01\*\* | 401.37\*\* |
| 6 | 633521 | -2.05 | -2.15 | -1.43 | -24.85\*\* | -19.38\*\* | 571.48\*\* |
| 7 | 545342 | 1.18 | 1.24 | -0.04 | 1.09 | 1.62 | 292.98\*\* |
| 8 | 563471 | -0.71 | -0.81 | -0.43 | -18.30\*\* | -7.88\*\* | -209.45\*\* |
| 9 | 563331 | -0.05 | 0.07 | -0.71 | -8.74\*\* | -9.21\*\* | -638.58\*\* |
| 10 | 563421 | -0.1 | -0.04 | -1.27 | -13.57\*\* | -7.93\*\* | -523.38\*\* |
| 11 | 633131 | 0.01 | 0.07 | 1.18 | -13.74\*\* | -6.21\*\* | -650.63\*\* |
| 12 | 621342 | -2.32 | -2.87\* | -2.43 | 0.43 | -4.65\*\* | -58.15\*\* |
| 13 | 563461 | -0.55 | -0.81 | -0.6 | -19.46\*\* | -9.43\*\* | 76.03\*\* |
| 14 | 563522 | -0.27 | -0.2 | -0.6 | -0.8 | -3.99\* | -138.99\*\* |
| 15 | 633151 | -1.1 | -0.59 | 0.18 | 1.87 | -1.32 | 19.86\*\* |
| 16 | 633211 | 0.4 | 0.35 | 0.9 | 15.09\*\* | 11.73\*\* | 583.76\*\* |
| 17 | 621341 | 0.29 | 0.41 | -0.15 | 6.70\*\* | -3.93\* | 726.41\*\* |
| 18 | 633241 | -1.55 | -1.65 | -1.6 | -7.46\*\* | -3.60\* | -652.94\*\* |
| 19 | 652241 | 0.9 | 0.69 | 1.85 | 17.09\*\* | 14.62\*\* | 255.88\*\* |
| 20 | 652431 | 1.62 | 1.85 | 0.9 | 1.26 | -0.21 | -210.33\*\* |
| 21 | 652321 | 1.51 | 1.57 | 1.4 | -6.30\*\* | -3.04\* | 92.70\*\* |
| 22 | 652141 | 0.57 | 0.3 | 1.46 | -5.24\*\* | -4.65\*\* | 197.37\*\* |
| 23 | 563521 | -1.21 | -1.43 | -0.1 | -3.02\*\* | -5.38\*\* | -360.34\*\* |
| Testers |
| 1 | CML-395/CML-202 | -0.04 | 0.01 | 0.51 | 2.93 | 3.89 | 569.62\*\* |
| 2 | CML-442/CML-312 | 0.04 | -0.01 | -0.51 | -2.93 | -3.89 | -569.62\*\* |

Table 5: Combined Specific combining ability of 46 three way crosses for yield and yield related traits at Yilmana Densa, Ayehu Guagusa and Hulet Eju Enese

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Line | Tester | DA | DS  | DM | PH | EH | GY |
| 1 | 1 | -0.18 | -0.40 | 0.27 | -5.15 | -1.83 | 659.88\*\* |
| 1 | 2 | 0.18 | 0.40 | -0.27 | 5.15 | 1.83 | -659.88\*\* |
| 2 | 1 | 0.88 | 0.93 | -0.57 | 8.18 | 3.00 | 1019.39\*\* |
| 2 | 2 | -0.88 | -0.93 | 0.57 | -8.18 | -3.00 | -1019.39\*\* |
| 3 | 1 | -0.12 | -0.07 | 0.77 | 7.68 | 4.61 | 1238.53\*\* |
| 3 | 2 | 0.12 | 0.07 | -0.77 | -7.68 | -4.61 | -1238.53\*\* |
| 4 | 1 | 1.27 | 1.21 | -0.62 | -2.43 | -1.22 | -479.72\*\* |
| 4 | 2 | -1.27 | -1.21 | 0.62 | 2.43 | 1.22 | 479.72\*\* |
| 5 | 1 | -0.23 | -0.18 | 0.21 | -3.71 | 3.11 | 452.76\*\* |
| 5 | 2 | 0.23 | 0.18 | -0.21 | 3.71 | -3.11 | -452.76\*\* |
| 6 | 1 | -0.35 | -0.07 | 0.43 | 1.18 | 0.39 | 601.72\*\* |
| 6 | 2 | 0.35 | 0.07 | -0.43 | -1.18 | -0.39 | -601.72\*\* |
| 7 | 1 | -0.23 | -0.24 | 0.27 | 6.68 | 5.39 | 1234.81\*\* |
| 7 | 2 | 0.23 | 0.24 | -0.27 | -6.68 | -5.39 | -1234.81\*\* |
| 8 | 1 | 1.21 | 1.49 | 0.54 | -3.37 | -0.89 | -781.22\*\* |
| 8 | 2 | -1.21 | -1.49 | -0.54 | 3.37 | 0.89 | 781.22\*\* |
| 9 | 1 | -0.90 | -1.07 | 0.49 | -4.04 | -5.55 | 137.75\*\* |
| 9 | 2 | 0.90 | 1.07 | -0.49 | 4.04 | 5.55 | -137.75\*\* |
| 10 | 1 | 0.04 | 0.04 | 0.27 | -5.32 | -3.50 | -882.6\*\* |
| 10 | 2 | -0.04 | -0.04 | -0.27 | 5.32 | 3.50 | 882.6\*\* |
| 11 | 1 | -0.51 | -0.63 | -0.07 | -6.15 | 1.67 | 304.45\*\* |
| 11 | 2 | 0.51 | 0.63 | 0.07 | 6.15 | -1.67 | -304.45\*\* |
| 12 | 1 | -0.85 | -1.01 | 0.21 | -6.87 | -3.44 | 71.77\*\* |
| 12 | 2 | 0.85 | 1.01 | -0.21 | 6.87 | 3.44 | -71.77\*\* |
| 13 | 1 | -0.73 | -0.74 | -0.62 | 3.13 | -1.55 | -334.69\*\* |
| 13 | 2 | 0.73 | 0.74 | 0.62 | -3.13 | 1.55 | 334.69\*\* |
| 14 | 1 | -0.12 | -0.35 | 0.04 | 5.57 | 3.00 | -233.83\*\* |
| 14 | 2 | 0.12 | 0.35 | -0.04 | -5.57 | -3.00 | 233.83\*\* |
| 15 | 1 | 0.82 | 1.37 | 0.15 | -5.21 | -4.44 | -1787.91\*\* |
| 15 | 2 | -0.82 | -1.37 | -0.15 | 5.21 | 4.44 | 1787.91\*\* |
| 16 | 1 | 0.43 | 0.54 | -0.46 | 4.68 | 5.06 | -472.23\*\* |
| 16 | 2 | -0.43 | -0.54 | 0.46 | -4.68 | -5.06 | 472.23\*\* |
| 17 | 1 | 0.32 | 0.04 | 0.15 | -1.26 | -2.83 | 302.04\*\* |
| 17 | 2 | -0.32 | -0.04 | -0.15 | 1.26 | 2.83 | -302.04\*\* |
| 18 | 1 | 0.15 | 0.21 | 0.27 | -2.99 | -2.61 | -855.21\*\* |
| 18 | 2 | -0.15 | -0.21 | -0.27 | 2.99 | 2.61 | 855.21\*\* |
| 19 | 1 | 0.27 | -0.35 | -0.85 | 1.57 | -1.50 | -714.58\*\* |
| 19 | 2 | -0.27 | 0.35 | 0.85 | -1.57 | 1.50 | 714.58\*\* |
| 20 | 1 | 0.21 | 0.26 | -0.01 | -1.15 | -1.11 | 265.17\*\* |
| 20 | 2 | -0.21 | -0.26 | 0.01 | 1.15 | 1.11 | -265.17\*\* |
| 21 | 1 | -0.57 | -0.68 | -0.07 | -3.26 | -1.94 | 304.20\*\* |
| 21 | 2 | 0.57 | 0.68 | 0.07 | 3.26 | 1.94 | -304.20\*\* |
| 22 | 1 | -0.29 | 0.15 | -0.35 | 8.35 | 8.67 | 469.56\*\* |
| 22 | 2 | 0.29 | -0.15 | 0.35 | -8.35 | -8.67 | -469.56\*\* |
| 23 | 1 | -0.51 | -0.46 | -0.46 | 3.90 | -2.50 | -520.05\*\* |
| 23 | 2 | 0.51 | 0.46 | 0.46 | -3.90 | 2.50 | 520.05\*\* |

\*= significant at 0.05 probability level

\*\*=significant at 0.01 probability level

 DA = days to anthesis (days), DS = days to silking (days), DM = days to maturity, PH = plant height (cm), EH = ear height (cm) and GY = grain yield (kg/ha).

Table 6: Heterotic grouping based on specific combining ability of grain yield for experiment

|  |  |  |  |
| --- | --- | --- | --- |
| Line | CML395/CML202 (Tester-1)(HB) | CML442/CML312 (Tester-2)(HA) |  |
| SCA of grain yield | SCA of grain yield | Heterotic grouping |
| 1 | 659.88\*\* | -659.88\*\* | A |
| 2 | 1019.39\*\* | -1019.39\*\* | A |
| 3 | 1238.53\*\* | -1238.53\*\* | A |
| 4 | -479.72\*\* | 479.72\*\* | B |
| 5 | 452.76\*\* | -452.76\*\* | A |
| 6 | 601.72\*\* | -601.72\*\* | A |
| 7 | 1234.81\*\* | -1234.81\*\* | A |
| 8 | -781.22\*\* | 781.22\*\* | B |
| 9 | 137.75\*\* | -137.75\*\* | A |
| 10 | -882.6\*\* | 882.6\*\* | B |
| 11 | 304.45\*\* | -304.45\*\* | A |
| 12 | 71.77\*\* | -71.77\*\* | A |
| 13 | -334.69\*\* | 334.69\*\* | B |
| 14 | -233.83\*\* | 233.83\*\* | B |
| 15 | -1787.91\*\* | 1787.91\*\* | B |
| 16 | -472.23\*\* | 472.23\*\* | B |
| 17 | 302.04\*\* | -302.04\*\* | A |
| 18 | -855.21\*\* | 855.21\*\* | B |
| 19 | -714.58\*\* | 714.58\*\* | B |
| 20 | 265.17\*\* | -265.17\*\* | A |
| 21 | 304.20\*\* | -304.20\*\* | A |
| 22 | 469.56\*\* | -469.56\*\* | A |
| 23 | -520.05\*\* | 520.05\*\* | B |

**CONCLUSION AND RECOMMENDATION**

Exploitation of hybrid vigor and selection of parents require information on the magnitude of

useful genetic variances present in the genotypes in terms of combining ability. Combining ability analysis is a useful genetic means to estimate GCA of parents and SCA of crosses to select the desired parents and crosses. Analysis of variance indicated the presence of genetic variation among genotypes by exhibiting significant difference among crosses for most studied traits. Three hybrids, hybrid 43 (9257.2 kgha−1), 5 (9498.3 kgha−1) and 13 (9097.9 kgha−1) showed better performance in grain yield compared to standard check AMH-851(Jibat), BH 546 and BH 661.

Information regarding combining ability is very important to select desirable parents and crosses. GCA analysis identified inbred lines L2, L3, L4, L6, L9, L13, L17, L20, L22 and L24 as good general combiners for grain yield. SCA effect analysis recognized that forty four three-way crosses were good specific combiners for grain yield. Heterotic grouping classified twenty six lines into heterotic group A and the remaining twenty one lines into heterotic group B. In general, the present investigation approved that inbred lines with good GCA, cross combinations with desirable SCA and classification of lines into different heterotic groups. So desirable hybrids can be developed by crossing lines from different heterotic group and synthetic varieties can be produced by using lines with good GCA effects within a heterotic group. Additionally, high yielding crosses with desirable SCA for grain yield would be tested in multi-location trial to identify better-performing crosses among them.

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Appendix Table 1: Pedigree of genotypes

|  |  |
| --- | --- |
| 48 crosses with 3 standard checks | 46 crosses with 3 standard checks |
| Entry | Pedigree | Entry | Pedigree | Entry | Pedigree | Entry | Pedigree |
| 1 | CML-395/CML-202//125433 | 27 | CML-395/CML-202//545341 | 1 | CML-395/CML-202//441311 | 26 | CML-442/CML-312//563461 |
| 2 | CML442/CML-312//125433 | 28 | CML-442/CML-312//545341 | 2 | CML-442/CML-312//441311 | 27 | CML-395/CML-202//563522 |
| 3 | CML-395/CML-202//125511 | 29 | CML-395/CML-202//545311 | 3 | CML-395/CML-202//363122 | 28 | CML-442/CML-312//563522 |
| 4 | CML-442/CML-312//125511 | 30 | CML-442/CML-312//545311 | 4 | CML-442/CML-312//363122 | 29 | CML-395/CML-202//633151 |
| 5 | CML-395/CML-202//125741 | 31 | CML-395/CML-202//125442 | 5 | CML-395/CML-202//421412 | 30 | CML-442/CML-312//633151 |
| 6 | CML-442/CML-312//125741 | 32 | CML-442/CML-312//125442 | 6 | CML-442/CML-312//421412 | 31 | CML-395/CML-202//633211 |
| 7 | CML-395/CML-202//137121 | 33 | CML-395/CML-202//125432 | 7 | CML-395/CML-202//421211 | 32 | CML-442/CML-312//633211 |
| 8 | CML-442/CML-312//137121 | 34 | CML-442/CML-312//125432 | 8 | CML-442/CML-312//421211 | 33 | CML-395/CML-202//621341 |
| 9 | CML-395/CML-202//215111 | 35 | CML-395/CML-202//442231 | 9 | CML-395/CML-202//344311 | 34 | CML-442/CML-312//621341 |
| 10 | CML-442/CML-312//215111 | 36 | CML-442/CML-312//442231 | 10 | CML-442/CML-312//344311 | 35 | CML-395/CML-202//633241 |
| 11 | CML-395/CML-202//215321 | 37 | CML-395/CML-202//163421 | 11 | CML-395/CML-202//633521 | 36 | CML-442/CML-312//633241 |
| 12 | CML-442/CML-312//215321 | 38 | CML-442/CML-312//163421 | 12 | CML-442/CML-312//633521 | 37 | CML-395/CML-202//652241 |
| 13 | CML-395/CML-202//215411 | 39 | CML-395/CML-202//125431 | 13 | CML-395/CML-202//545342 | 38 | CML-442/CML-312//652241 |
| 14 | CML-442/CML-312//215411 | 40 | CML-442/CML-312//125431 | 14 | CML-442/CML-202//545342 | 39 | CML-395/CML-202//652431 |
| 15 | CML-395/CML-202//441221 | 41 | CML-395/CML-202//633152 | 15 | CML-395/CML-202//563471 | 40 | CML-442/CML-312//652431 |
| 16 | CML-442/CML-312//441221 | 42 | CML-442/CML-312//633152 | 16 | CML-442/CML-312//563471 | 41 | CML-395/CML-202//652321 |
| 17 | CML-395/CML-202//421521 | 43 | CML-395/CML-202//633321 | 17 | CML-395/CML-202//563331 | 42 | CML-442/CML-312//652321 |
| 18 | CML-442/CML-312//421521 | 44 | CML-442/CML-312//633321 | 18 | CML-442/CML-312//563331 | 43 | CML-395/CML-202//652141 |
| 19 | CML-395/CML-202//527131 | 45 | CML-395/CML-202//421411 | 19 | CML-395/CML-202//563421 | 44 | CML-442/CML-312//652141 |
| 20 | CML-442/CML-312//527131 | 46 | CML-442/CML-312//421411 | 20 | CML-442/CML-312//563421 | 45 | CML-395/CML-202//563521 |
| 21 | CML-395/CML-202//545411 | 47 | CML-395/CML-202//563121 | 21 | CML-395/CML-202//633131 | 46 | CML-442/CML-312//563521 |
| 22 | CML-442/CML-312//545411 | 48 | CML-442/CML-312//563121 | 22 | CML-442/CML-312//633131 | 47 | BH 661 |
| 23 | CML-395/CML-202//125441 | 49 | BH 661 | 23 | CML-395/CML-202//621342 | 48 | BH 546 |
| 24 | CML-442/CML-312//125441 | 50 | BH 546 | 24 | CML-442/CML-312//621342 | 49 | AMH 851 |
| 25 | CML-395/CML-202//442232 | 51 | AMH 851 |  25 | CML-395/CML-202//563461 |  |  |
| 26 | CML-442/CML-312//442232 |  |  |  |  |  |  |

Appendix Table 2: Combined mean performance of 48 crosses and 3 checks for yield and yield related traits at Yilmana Densa, Ayehu Guagusa, Jabitehinan

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Entry | Genotype | DA | DS | DM | PH | EH | GLS | CR | TLB | EA | PA | GY |
|  1 | CML-395/CML-202//125433 | 87.2 | 89.8 | 153.7 | 239.0 | 136.3 | 1.61 | 1.50 | 2.06 | 2.06 | 2.11 | 7044.6 |
|  2 | CML442/CML-312//125433 | 86.8 | 88.8 | 152.7 | 251.0 | 135.7 | 1.67 | 1.56 | 1.94 | 1.94 | 2.06 | 7368.7 |
|  3 | CML-395/CML-202//125511 | 88.8 | 91.1 | 154.2 | 245.9 | 135.6 | 1.56 | 1.50 | 1.67 | 1.50 | 1.94 | 8391.5 |
|  4 | CML-442/CML-312//125511 | 89.2 | 91.6 | 153.2 | 238.7 | 128.4 | 1.61 | 1.56 | 2.00 | 2.06 | 2.28 | 6709.0 |
|  5 | CML-395/CML-202//125741 | 86.9 | 89.3 | 152.8 | 247.2 | 130.4 | 1.56 | 1.56 | 1.89 | 1.89 | 2.28 | 7848.9 |
|  6 | CML-442/CML-312//125741 | 86.9 | 89.4 | 152.1 | 240.7 | 127.0 | 1.72 | 1.67 | 2.11 | 2.22 | 2.39 | 5417.3 |
|  7 | CML-395/CML-202//137121 | 88.0 | 90.2 | 154.2 | 239.3 | 142.3 | 1.67 | 1.61 | 1.89 | 1.61 | 1.89 | 7517.8 |
|  8 | CML-442/CML-312//137121 | 87.6 | 90.0 | 153.1 | 248.4 | 134.8 | 1.56 | 1.50 | 2.06 | 1.78 | 2.17 | 6733.0 |
|  9 | CML-395/CML-202//215111 | 86.2 | 89.0 | 152.6 | 244.8 | 138.0 | 1.67 | 1.56 | 1.67 | 1.83 | 2.00 | 8197.2 |
|  10 | CML-442/CML-312//215111 | 86.1 | 88.7 | 152.1 | 251.7 | 131.8 | 1.78 | 1.67 | 2.06 | 2.11 | 2.33 | 6249.7 |
|  11 | CML-395/CML-202//215321 | 86.7 | 88.9 | 153.3 | 245.4 | 140.1 | 1.67 | 1.67 | 1.78 | 1.89 | 2.17 | 7824.2 |
|  12 | CML-442/CML-312//215321 | 87.2 | 89.7 | 152.7 | 246.0 | 134.2 | 1.78 | 1.56 | 1.94 | 2.06 | 2.17 | 7274.1 |
|  13 | CML-395/CML-202//215411 | 83.0 | 88.2 | 153.1 | 242.8 | 137.7 | 1.67 | 1.61 | 1.78 | 2.11 | 2.22 | 7646.4 |
|  14 | CML-442/CML-312//215411 | 86.7 | 88.6 | 152.1 | 239.0 | 135.3 | 1.89 | 1.61 | 1.89 | 2.33 | 2.33 | 6052.2 |
|  15 | CML-395/CML-202//441221 | 86.6 | 89.2 | 154.3 | 265.7 | 155.0 | 1.56 | 1.56 | 1.72 | 1.61 | 1.78 | 8140.2 |
|  16 | CML-442/CML-312//441221 | 85.4 | 87.9 | 151.9 | 243.8 | 134.7 | 1.56 | 1.50 | 1.72 | 2.17 | 2.00 | 6188.5 |
|  17 | CML-395/CML-202//421521 | 87.0 | 89.8 | 154.3 | 249.7 | 147.6 | 1.61 | 1.50 | 1.67 | 1.67 | 1.72 | 8445.7 |
|  18 | CML-442/CML-312//421521 | 86.6 | 89.1 | 153.1 | 243.8 | 140.9 | 1.61 | 1.61 | 1.89 | 2.22 | 2.06 | 7167.6 |
|  19 | CML-395/CML-202//527131 | 84.9 | 87.8 | 152.8 | 228.4 | 125.3 | 1.83 | 1.61 | 1.78 | 1.61 | 2.28 | 6157.4 |
|  20 | CML-442/CML-312//527131 | 85.3 | 87.7 | 151.9 | 242.1 | 127.9 | 1.67 | 1.56 | 1.83 | 2.11 | 2.17 | 6358.1 |
|  21 | CML-395/CML-202//545411 | 86.9 | 89.1 | 152.0 | 239.2 | 138.7 | 1.72 | 1.67 | 2.06 | 2.11 | 2.28 | 6482.6 |
| 22 | CML-442/CML-312//545411 | 86.8 | 89.0 | 150.9 | 243.2 | 132.6 | 1.61 | 1.61 | 2.17 | 2.28 | 2.28 | 6330.5 |
| 23 | CML-395/CML-202//125441 | 89.8 | 92.2 | 154.0 | 254.1 | 147.8 | 1.83 | 1.72 | 1.78 | 1.83 | 2.00 | 8270.8 |
|  24 | CML-442/CML-312//125441 | 89.2 | 91.4 | 152.2 | 249.4 | 141.0 | 1.89 | 1.78 | 2.00 | 2.33 | 2.00 | 6320.0 |
|  25 | CML-395/CML-202//442232 | 86.1 | 88.6 | 153.7 | 252.7 | 151.8 | 1.61 | 1.56 | 1.78 | 2.00 | 2.11 | 7910.7 |
|  26 | CML-442/CML-312//442232 | 87.0 | 89.3 | 152.4 | 250.2 | 144.0 | 1.67 | 1.61 | 1.94 | 2.06 | 2.11 | 7346.0 |
|  27 | CML-395/CML-202//545341 | 85.9 | 88.0 | 153.3 | 239.3 | 131.2 | 1.56 | 1.44 | 1.67 | 1.89 | 1.83 | 8078.9 |
|  28 | CML-442/CML-312//545341 | 86.8 | 89.4 | 151.6 | 223.2 | 122.1 | 1.50 | 1.44 | 1.78 | 2.50 | 2.17 | 6302.1 |
|  29 | CML-395/CML-202//545311 | 87.1 | 89.2 | 153.1 | 242.9 | 141.0 | 1.72 | 1.61 | 1.72 | 1.83 | 1.89 | 7029.0 |
|  30 | CML-442/CML-312//545311 | 87.5 | 89.6 | 152.4 | 233.9 | 128.7 | 1.61 | 1.50 | 1.78 | 2.33 | 2.39 | 5409.8 |
|  31 | CML-395/CML-202//125442 | 88.6 | 91.2 | 154.3 | 253.3 | 145.6 | 1.67 | 1.61 | 1.72 | 1.68 | 1.83 | 7982.5 |
|  32 | CML-442/CML-312//125442 | 87.6 | 89.9 | 152.7 | 243.9 | 137.3 | 1.61 | 1.61 | 1.94 | 2.17 | 2.22 | 5839.2 |
|  33 | CML-395/CML-202//125432 | 88.9 | 91.4 | 154.8 | 254.0 | 149.2 | 1.61 | 1.56 | 1.72 | 1.61 | 2.22 | 8427.6 |
|  34 | CML-442/CML-312//125432 | 87.3 | 89.9 | 153.8 | 240.3 | 135.6 | 1.72 | 1.61 | 1.89 | 2.00 | 2.00 | 7317.8 |
|  35 | CML-395/CML-202//442231 | 90.9 | 92.0 | 154.8 | 257.8 | 152.4 | 1.50 | 1.50 | 1.83 | 1.67 | 2.22 | 7333.3 |
|  36 | CML-442/CML-312//442231 | 87.9 | 90.7 | 153.4 | 245.3 | 143.6 | 1.56 | 1.50 | 1.94 | 1.83 | 2.39 | 7243.0 |
|  37 | CML-395/CML-202//163421 | 86.7 | 88.8 | 152.4 | 227.9 | 133.8 | 1.78 | 1.78 | 2.11 | 1.78 | 2.50 | 7192.1 |
|  38 | CML-442/CML-312//163421 | 85.9 | 88.0 | 152.0 | 247.2 | 129.4 | 1.78 | 1.61 | 2.06 | 2.28 | 2.33 | 6658.4 |
|  39 | CML-395/CML-202//125431 | 86.9 | 88.9 | 153.4 | 236.4 | 125.3 | 1.56 | 1.50 | 1.78 | 1.56 | 2.28 | 8416.1  |
|  40 | CML-442/CML-312//125431 | 86.2 | 88.8 | 152.2 | 224.6 | 123.9 | 1.50 | 1.44 | 1.78 | 1.89 | 1.94 | 7128.2 |
|  41 | CML-395/CML-202//633152 | 86.7 | 89.1 | 154.0 | 238.8 | 134.9 | 1.61 | 1.56 | 1.72 | 2.22 | 2.00 | 8580.5 |
|  42 | CML-442/CML-312//633152 | 86.4 | 88.3 | 153.3 | 228.7 | 124.9 | 1.56 | 1.50 | 1.83 | 2.22 | 2.50 | 5785.0 |
|  43 | CML-395/CML-202//633321 | 86.8 | 89.3 | 154.7 | 264.0 | 154.2 | 1.61 | 1.56 | 1.61 | 2.56 | 1.89 | 9257.2 |
|  44 | CML-442/CML-312//633321 | 86.9 | 89.4 | 152.1 | 235.9 | 126.7 | 1.50 | 1.50 | 1.72 | 2.44 | 2.28 | 6859.7 |
|  45 | CML-395/CML-202//421411 | 86.1 | 88.4 | 153.2 | 241.6 | 137.8 | 1.50 | 1.50 | 1.78 | 1.44 | 2.11 | 8053.4 |
|  46 | CML-442/CML-312//421411 | 85.2 | 87.4 | 152.2 | 233.6 | 130.1 | 1.56 | 1.50 | 1.89 | 2.00 | 2.11 | 6714.8 |
|  47 | CML-395/CML-202//563121 | 85.4 | 88.2 | 154.0 | 235.7 | 129.4 | 1.50 | 1.44 | 1.72 | 1.67 | 2.06 | 8332.3 |
|  48 | CML-442/CML-312//563121 | 86.8 | 89.2 | 153.0 | 229.6 | 130.3 | 1.50 | 1.39 | 1.72 | 1.83 | 2.22 | 7062.9 |
|  49 | BH-661 | 89.7 | 91.7 | 157.6 | 286.4 | 173.0 | 1.44 | 1.44 | 1.83 | 1.39 | 2.00 | 10379.0 |
|  50 | BH-546 | 87.8 | 90.2 | 155.9 | 261.0 | 145.6 | 1.56 | 1.44 | 1.72 | 1.39 | 2.00 | 9163.7 |
|  51 | AMH-851 | 84.9 | 87.0 | 152.4 | 251.1 | 131.6 | 1.50 | 1.50 | 1.67 | 2.06 | 1.89 | 8889.7 |
|   | MEAN | 86.9 | 89.4 | 153.2 | 244.3 | 137.1 | 1.63 | 1.56 | 1.84 | 1.95 | 2.13 | 7349.6 |
|   | LSD | 1.69 | 1.49 | 1.45 | 11.70 | 9.26 | 0.23 | 0.19 | 0.19 | 0.34 | 0.40 | 999.64 |
|   | CV | 2.10 | 1.80 | 1.02 | 5.16 | 7.28 | 15.07 | 13.13 | 10.84 | 18.74 | 20.49 | 14.54 |
|   | GENOTYPE(G) | \*\* | \*\* | \*\* | \*\* | \*\* | \* | NS | \*\* | \*\* | \* | \*\* |
|  | LOCATION(L) | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* |
|  | GXL | \*\* | \*\* | \*\* | NS | \* | NS | NS | \*\* | \* | NS | \*\* |

\*\*=significant at 0.01 probability level, \*= significant at 0.05 probability level and NS= Non significant

 DA = days to anthesis (days), DS = days to silking (days), DM = days to maturity, PH = plant height (cm), EH = ear height (cm), GLS = gery leaf spot, CR = corn rust, TLB = Turcicum leaf blight, EA = ear aspect, PA = plant aspect and GY = grain yield (kg/ha).

Appendix Table 3: Combined mean performance of 46 crosses and 3 checks for yield and yield related traits at Yilmana Densa, Ayehu Guagusa, Hulet Eju Enes

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Entry | Genotype | DA | DS | DM | PH | EH | GLS | CR | TLB | EA | PA | GY(kg) |
| 1 | CML-395/CML-202//441311 | 92.33 | 94.56 | 162.67 | 236.67 | 137.22 | 1.22 | 1.28 | 1.39 | 1.72 | 2.50 | 8144.8 |
| 2 | CML-442/CML-312//441311 | 92.78 | 95.33 | 161.11 | 241.11 | 133.11 | 1.39 | 1.39 | 1.44 | 2.61 | 2.61 | 5685.7 |
| 3 | CML-395/CML-202//363122 | 93.78 | 96.22 | 159.67 | 245.89 | 142.67 | 1.56 | 1.39 | 1.56 | 1.94 | 2.44 | 7524.3 |
| 4 | CML-442/CML-312//363122 | 92.11 | 94.33 | 159.78 | 223.67 | 128.89 | 1.61 | 1.56 | 1.83 | 2.50 | 2.56 | 4346.3 |
| 5 | CML-395/CML-202//421412 | 91.00 | 93.33 | 161.33 | 232.78 | 139.33 | 1.33 | 1.33 | 1.39 | 1.33 | 2.17 | 9498.3 |
| 6 | CML-442/CML-312//421412 | 91.33 | 93.44 | 158.78 | 211.56 | 122.33 | 1.44 | 1.33 | 1.50 | 2.00 | 2.56 | 5882 |
| 7 | CML-395/CML-202//421211 | 92.78 | 95.22 | 161.11 | 222.78 | 137.11 | 1.44 | 1.33 | 1.33 | 1.61 | 2.39 | 7775.9 |
| 8 | CML-442/CML-312//421211 | 90.33 | 92.78 | 161.33 | 221.78 | 131.78 | 1.39 | 1.17 | 1.44 | 2.11 | 2.17 | 7596.1 |
| 9 | CML-395/CML-202//344311 | 92.67 | 95.56 | 162.33 | 256.11 | 159.11 | 1.67 | 1.44 | 1.56 | 1.44 | 2.17 | 8424.2 |
| 10 | CML-442/CML-312//344311 | 93.22 | 95.89 | 160.89 | 257.67 | 145.11 | 1.67 | 1.56 | 1.61 | 1.78 | 2.50 | 6379.4 |
| 11 | CML-395/CML-202//633521 | 89.11 | 91.67 | 160.11 | 198.67 | 110.00 | 1.50 | 1.44 | 1.44 | 2.11 | 2.22 | 8743.3 |
| 12 | CML-442/CML-312//633521 | 89.89 | 91.78 | 158.22 | 190.44 | 101.44 | 1.44 | 1.39 | 1.50 | 2.50 | 2.83 | 6400.6 |
| 13 | CML-395/CML-202//545342 | 92.44 | 94.89 | 161.33 | 230.11 | 136.00 | 1.44 | 1.33 | 1.33 | 1.72 | 2.17 | 9097.9 |
| 14 | CML-442/CML-202//545342 | 93.00 | 95.33 | 159.78 | 210.89 | 117.44 | 1.44 | 1.33 | 1.44 | 2.22 | 2.61 | 5489 |
| 15 | CML-395/CML-202//563471 | 92.00 | 94.56 | 161.22 | 200.67 | 120.22 | 1.44 | 1.33 | 1.44 | 1.56 | 2.67 | 6579.4 |
| 16 | CML-442/CML-312//563471 | 89.67 | 91.56 | 159.11 | 201.56 | 114.22 | 1.39 | 1.39 | 1.56 | 2.11 | 2.44 | 7002.6 |
| 17 | CML-395/CML-202//563331 | 90.56 | 92.89 | 160.89 | 209.56 | 114.22 | 1.28 | 1.22 | 1.67 | 1.67 | 2.22 | 7069.2 |
| 18 | CML-442/CML-312//563331 | 92.44 | 95.00 | 158.89 | 211.78 | 117.56 | 1.50 | 1.50 | 1.94 | 2.22 | 2.50 | 5654.5 |
| 19 | CML-395/CML-202//563421 | 91.44 | 93.89 | 160.11 | 203.44 | 117.56 | 1.33 | 1.39 | 1.56 | 1.72 | 2.44 | 6164.1 |
| 20 | CML-442/CML-312//563421 | 91.44 | 93.78 | 158.56 | 208.22 | 116.78 | 1.39 | 1.33 | 1.56 | 2.00 | 2.50 | 6790 |
| 21 | CML-395/CML-202//633131 | 91.00 | 93.33 | 162.22 | 202.44 | 124.44 | 1.44 | 1.44 | 1.39 | 2.06 | 2.44 | 7223.9 |
| 22 | CML-442/CML-312//633131 | 92.11 | 94.56 | 161.33 | 208.89 | 113.33 | 1.56 | 1.50 | 1.72 | 2.44 | 2.78 | 5475.7 |
| 23 | CML-395/CML-202//621342 | 88.33 | 90.00 | 158.89 | 215.89 | 120.89 | 1.61 | 1.56 | 1.61 | 1.89 | 2.56 | 7583.7 |
| 24 | CML-442/CML-312//621342 | 90.11 | 92.00 | 157.44 | 223.78 | 120.00 | 1.67 | 1.56 | 1.78 | 2.22 | 2.61 | 6300.9 |
| 25 | CML-395/CML-202//563461 | 90.22 | 92.33 | 159.89 | 206.00 | 118.00 | 1.33 | 1.33 | 1.50 | 1.72 | 2.39 | 7311.4 |
| 26 | CML-442/CML-312//563461 | 91.78 | 93.78 | 160.11 | 193.89 | 113.33 | 1.17 | 1.22 | 1.44 | 2.11 | 2.67 | 6841.5 |
| 27 | CML-395/CML-202//563522 | 91.11 | 93.33 | 160.56 | 227.11 | 128.00 | 1.44 | 1.39 | 1.61 | 1.72 | 2.28 | 7197.2 |
| 28 | CML-442/CML-312//563522 | 91.44 | 94.00 | 159.44 | 210.11 | 114.22 | 1.39 | 1.39 | 1.56 | 2.06 | 2.33 | 6525.6 |
| 29 | CML-395/CML-202//633151 | 91.22 | 94.67 | 161.44 | 219.00 | 123.22 | 1.50 | 1.39 | 1.56 | 2.06 | 2.67 | 5802 |
| 30 | CML-442/CML-312//633151 | 89.67 | 91.89 | 160.11 | 223.56 | 124.33 | 1.44 | 1.44 | 1.56 | 2.28 | 2.44 | 8238.6 |
| 31 | CML-395/CML-202//633211 | 92.33 | 94.78 | 161.56 | 242.11 | 145.78 | 1.39 | 1.33 | 1.39 | 1.89 | 2.33 | 7681.6 |
| 32 | CML-442/CML-312//633211 | 91.56 | 93.67 | 161.44 | 226.89 | 127.89 | 1.44 | 1.33 | 1.44 | 2.22 | 2.22 | 7486.8 |
| 33 | CML-395/CML-202//621341 | 92.11 | 94.33 | 161.11 | 227.78 | 122.22 | 1.50 | 1.44 | 1.39 | 1.78 | 2.50 | 8598.5 |
| 34 | CML-442/CML-312//621341 | 91.56 | 94.22 | 159.78 | 224.44 | 120.11 | 1.67 | 1.61 | 1.56 | 2.50 | 2.67 | 6855.2 |
| 35 | CML-395/CML-202//633241 | 90.11 | 92.44 | 159.78 | 211.89 | 122.78 | 1.56 | 1.44 | 1.72 | 1.94 | 2.61 | 6061.9 |
| 36 | CML-442/CML-312//633241 | 89.89 | 92.00 | 158.22 | 212.00 | 120.22 | 1.56 | 1.50 | 1.72 | 2.11 | 2.44 | 6633.1 |
| 37 | CML-395/CML-202//652241 | 92.67 | 94.22 | 162.11 | 241.00 | 142.11 | 1.61 | 1.56 | 1.56 | 1.67 | 2.39 | 7111.4 |
| 38 | CML-442/CML-312//652241 | 92.22 | 94.89 | 162.78 | 232.00 | 137.33 | 1.50 | 1.50 | 1.61 | 2.17 | 2.44 | 7401.3 |
| 39 | CML-395/CML-202//652431 | 93.33 | 96.00 | 162.00 | 222.44 | 127.67 | 1.33 | 1.33 | 1.44 | 1.50 | 2.22 | 7624.9 |
| 40 | CML-442/CML-312//652431 | 93.00 | 95.44 | 161.00 | 218.89 | 122.11 | 1.50 | 1.50 | 1.61 | 2.11 | 2.50 | 5955.3 |
| 41 | CML-395/CML-202//652321 | 92.44 | 94.78 | 162.44 | 212.78 | 124.00 | 1.56 | 1.50 | 1.50 | 1.44 | 2.44 | 7967.0 |
| 42 | CML-442/CML-312//652321 | 93.67 | 96.11 | 161.56 | 213.44 | 120.11 | 1.61 | 1.61 | 1.67 | 2.17 | 2.61 | 6219.3 |
| 43 | CML-395/CML-202//652141 | 91.78 | 94.33 | 162.22 | 225.44 | 133.00 | 1.50 | 1.56 | 1.44 | 1.56 | 2.39 | 8237.0 |
| 44 | CML-442/CML-312//652141 | 92.44 | 94.00 | 161.89 | 202.89 | 107.89 | 1.44 | 1.39 | 1.56 | 1.94 | 2.39 | 6158.6 |
| 45 | CML-395/CML-202//563521 | 89.78 | 92.00 | 160.56 | 223.22 | 121.11 | 1.44 | 1.39 | 1.50 | 1.94 | 2.28 | 6689.7 |
| 46 | CML-442/CML-312//563521 | 90.89 | 92.89 | 160.44 | 209.56 | 118.33 | 1.50 | 1.56 | 1.56 | 2.17 | 2.33 | 6590.5 |
| 47 | BH-661 | 94.11 | 96.56 | 163.33 | 279.78 | 173.44 | 1.33 | 1.39 | 1.56 | 1.61 | 2.56 | 9066.5 |
| 48 | BH-546 | 93.56 | 95.78 | 162.44 | 238.78 | 147.56 | 1.50 | 1.50 | 1.61 | 1.78 | 2.33 | 8612.9 |
| 49 | AMH-851 | 88.11 | 90.11 | 160.22 | 225.11 | 116.56 | 1.39 | 1.33 | 1.44 | 2.17 | 2.00 | 7910.2 |
|   | MEAN | 91.57 | 93.89 | 160.68 | 221.15 | 126.37 | 1.46 | 1.42 | 1.54 | 1.96 | 2.44 | 7094.1 |
|   | LSD |  1.60 |  1.83 |  1.54 |  16.47 |  9.53 |  0.25 |  0.19 |  0.20 |  0.30 | 0.37 | 1294.90 |
|   | CV | 1.88 | 2.10 | 1.03 | 8.03 | 8.12 | 18.54 | 14.56 | 13.97 | 16.62 | 16.44 | 19.67 |
|   | GENOTYPE(G) | \*\* | \*\* | \*\* | \*\* | \*\* | \* | \*\* | \*\* | \*\* | \*\* | \*\* |
|  | LOCATION(L) | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* |
|  | GXL | \*\* | \*\* | \* | NS | NS | \*\* | \* | \*\* | NS | NS | \* |

\*\*=significant at 0.01 probability level, \*= significant at 0.05 probability level and NS= Non significant

 DA = days to anthesis (days), DS = days to silking (days), DM = days to maturity, PH = plant height (cm), EH = ear height (cm), GLS = gery leaf spot, CR = corn rust, TLB = Turcicum leaf blight, EA = ear aspect, PA = plant aspect and GY = grain yield (kg/ha).