Hybrid maize genotypes test cross performance on agronomic traits

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Abstract. Maize production in Indonesia has increased significantly in the last five years. Various programs have been introduced by the government to support maize cropping system and increase yield per ha. In order to obtain a suitable hybrid combination, improvement of breeding program is obligatory. The objectives of the research were to determine the combining ability between lines and testers, and to evaluate the performance of crosses for agronomic component traits. Six inbred lines were test crossed with two male testers using line x tester mating design. Randomized complete block design was used as an experimental design with three replications at three locations in Indonesia. Results indicate that inbred line MYL7 had a positive and significant GCA effects for days to silking, maturity, ear diameter. Test cross MYL7×MAL01 had positive and significant SCA effect for ear length, MYL15×MAL01 for 1000-seed weight, and MYL10×MR14 for days to silking. Depend on the purpose of breeding program, each superior combination can be further explored for a specific use.

1. Introduction

Hybrid maize has made significant contributions to the national production in Indonesia. Hybrid crossing in maize crop has been the most extensively studied including conventional and molecular based varietal development. Various methods have been applied to improve the selection of genes controlling the desired agronomic characters. A common approach for assessing the expression of genetic aspects of traits is line x tester analysis [1]. Estimation of combining ability can be used to determine the usefulness of the inbred lines in hybrid combinations and to developed superior hybrid adaptable to the wider environments.

Maize breeders have been developing various quantitative estimation of GCA and SCA for determining the most suitable crossing. Application of GCA and SCA will enhance the opportunity for getting best combination among maize populations [2]. In addition, the affectivity of SCA parameter for identifying the tolerance of maize inbreds to the MRC disease have reported in Argentina [3]. Furthermore, GCA/SCA based selection would increase the possibility of selecting maize inbreds associated with heat stress tolerance in order to avoid yield losses due to the high temperature and extreme heat waves [4]. Significant role of GCA for regulating various agronomic components of maize inbreds viz., seed rows per ear, but vice versa for grain yield and seeds per row have investigated by Dehghanpour and Ehsaie [5]. Viana and Matta [6] investigated the greater contribution of dominance effects in regulating agronomic components of white corn genotypes.
The objectives of the research were to assess the combining ability of crosses for agronomic traits such as plant height, anthesis to maturity days, ear height, ear aspect, maturity and other important characters. Hence, the present study was to assess the GCA and SCA of six maize inbreds based on agronomic characters.

2. Materials and Methods
Testing of inbred were conducted at three diverse locations i.e. Bone Regency, South Sulawesi, Lombok, West Nusa Tenggara, and Probolinggo Regency, East Java. The soil types of Bone, Mataram and Probolinggo are characterized by Alfisol, Regosol, and Andosol and the area receive average annual rainfall of 2,485 mm, 1,557 mm and 1,929 mm respectively. Six inbred lines viz., MYL2, MYL7, MYL10, MYL12, MYL15, and MYL16 (used as males) and two testers’ viz., MR14 and MAL01 were crossed and evaluated for the combining ability across locations. The inbred lines were selected based on vigor and adaptation to tropical agro-ecologies of Indonesia. The inbred testers MR14 and Mal01 were elite inbred lines with good combining ability. The data were recorded on yield and yield components such as days to anthesis, days to silking, plant height, ear height, ear length, ear diameter, 1000 kernel weight. All the crop management practices were applied based on the recommendation of each location. Analysis of variance was first carried out for each location, and later subjected to combined analysis. The environment effects were treated as random and cross effects as fixed. The procedure of line x tester analysis was performed for each environment using the method described by [7].

3. Results and discussion
The GCA effects for plant height, days of silking, ear length, ear diameter, plant height, maturity and yield components such as days to anthesis, days to silking, plant height, ear height, ear length, ear diameter, 1000 kernel weight. All the crop management practices were applied based on the recommendation of each location. Analysis of variance was first carried out for each location, and later subjected to combined analysis. The environment effects were treated as random and cross effects as fixed. The procedure of line x tester analysis was performed for each environment using the method described by [7].

| Table 1. General combining ability effects for components traits in maize |
|-------------------------------------------------|
| Characters          | Locations | L1  | L2  | L3  | L4  | L5  | L6  | T1  | T2  |
| Plant height        | Bone      | 5.47| -6.66| -3.86| 11.94| -3.49| -5.39| 2.32| -2.32|
|                    | Mataram   | 3.63| -2.03| -1.70| -2.70| -7.33| 10.13| 3.28| -3.28|
|                    | Probolinggo| -1.23| 8.37| 0.50| 10.07| -13.00| -4.70| 1.82| -1.82|
|                    | Across    | 2.62| 0.56| -1.69| 6.44| -7.94| 0.01| 2.47| -2.47|

| Days of silking     | Bone      | 0.69| 1.53| -1.47| -0.14| 1.19| -1.81| -0.31| 0.31|
|                    | Mataram   | 0.47| 0.47| 1.14| -1.86| 1.14| -1.36| -0.25| 0.25|
|                    | Probolinggo| 0.33| 1.50| 1.00| -1.50| -1.83| 0.5| -0.72| 0.72|
|                    | Across    | 0.5| 1.17| 0.22| -1.17| 0.17| -0.89| -0.43| 0.43|

| Maturity           | Bone      | 0.86| 1.69| -0.31| -0.81| 0.36| -1.81| 0.31| -0.31|
|                    | Mataram   | 0.11| 0.73| 1.46| -2.07| 1.20| -1.44| -0.32| 0.32|
|                    | Probolinggo| 0.22| 1.39| 0.89| -0.94| -1.94| 0.39| -0.61| 0.61|
|                    | Across    | 0.40| 1.27| 0.68| -1.27| -0.13| -0.95| -0.21| 0.21|

| Ear diameter       | Bone      | -0.16| 0.21| 0.14| -0.04| 0.01| -0.17| -0.12| 0.12|
|                    | Mataram   | 0.12| -0.01| 0.03| -0.08| 0.00| -0.08| -0.04| 0.04|
|                    | Probolinggo| -0.08| 0.13| 0.03| 0.04| 0.01| -0.12| -0.10| 0.10|
|                    | Across    | -0.04| 0.11| 0.07| -0.03| 0.01| -0.12| 0.09| -0.09|

| Ear length         | Bone      | -0.61| 1.03| 0.12| -1.30| 0.53| 0.23| -0.48| 0.48|
|                    | Mataram   | -0.29| -0.82| -0.17| 0.06| 0.36| 0.86| -0.76| 0.76|
|                    | Probolinggo| -0.04| 0.19| 0.07| -0.19| 0.03| -0.13| -0.41| 0.41|
|                    | Across    | -0.29| 0.13| 0.00| -0.48| 0.31| 0.32| -0.55| 0.55|

| 1000 kernel weight | Bone      | 1.84| 1.36| 2.27| -20.13| -8.07| 12.89| 17.22| -17.22|
|                    | Mataram   | -8.90| -12.55| -21.87| 15.11| -3.27| 18.01| -9.65| 9.65|
|                    | Probolinggo| -5.76| 6.56| -7.11| 6.09| -5.41| 6.12| -1.91| 1.91|
|                    | Across    | -4.27| -1.55| -8.90| 0.36| -5.59| 9.39| 1.89| -1.89|

Note: L=maize line/genotype
Estimates of general combining ability across locations for plant height showed significant and negative GCA effects for MYL15. The results exhibited that lines MYL10 (L3), MYL15 (L5) and tester MR14 (T2) were a good general combiner, hence MYL10 (L3), MYL15 (L5) and tester MR14 (T2) can be used as potential source of additive gene effects to improve yield and secondary traits [8].

Estimates of GCA for days to silking showed MYL 12 (L4) line and MAL 01 (T1) tester were an ideal combiner as these inbreds lines had gene combinations that enhance early maturity. Significant and negative GCA effect is desirable for breeding early maturity maize particularly for short rainy season and dry areas [9]. Estimates of GCA for plant height and ear height showed MYL 15 (L5) line and MR 14 (T2) were good combiners for both plant and ear heights. Plant height and ear height are two important agronomic traits in maize selection breeding. Shorter plant height and medium ear placement is desirable for lodging resistance and mechanized agriculture [10]. Furthermore, Ali et al. [11], found that greater ear height is undesirable because the ear placement at a greater height from the ground level exerts pressure on plant during grain filling and physiological maturity and causes lodging, which could ultimately affect maize yield.

### Table 2. Specific combining ability effects for yield and yield components traits in maize

| Locations | L1×T1 | L1×T2 | L2×T1 | L2×T2 | L3×T1 | L3×T2 | L4×T1 | L4×T2 | L5×T1 | L5×T2 | L6×T1 | L6×T2 |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| **Plant Height** |
| Bone      | 15.46 | -15.46| 10.64 | 10.64 | 1.26  | -1.26 | 0.06  | -0.06 | -8.17 | 8.17  | 2.03  | -2.03 |
| Mataram   | -1.94 | 1.94  | 10.72 | -10.72| 0.06  | -0.06 | 7.39  | -7.39 | -4.11 | 4.11  | -12.11| 12.11 |
| Probolinggo| -4.86 | 4.86  | -3.99 | 3.99  | 4.74  | -4.74 | 2.98  | -2.98 | 1.24  | -1.24| -0.12 | 0.12  |
| Across    | 2.89  | -2.89 | -1.30 | 1.30  | 2.02  | -2.02 | 3.48  | -3.48 | -3.86 | 3.86  | -3.40 | 3.40  |
| **Days of silking** |
| Bone      | -0.69 | 0.69  | 0.81  | -0.81 | 0.47  | -0.47 | -1.19 | 1.19  | 0.47  | -0.47| 0.14  | -0.14 |
| Mataram   | -0.92 | 0.92  | -0.58 | 0.58  | 0.42  | -0.42 | 0.42  | -0.42 | 0.42  | -0.42| 0.25  | -0.25 |
| Probolinggo| 0.56  | -0.56 | 0.39  | -0.39 | 1.22  | -1.22 | -1.28 | 1.28  | 1.61  | -1.61| 0.72  | -0.72 |
| Across    | -0.35 | 0.35  | 0.20  | -0.20 | 0.77  | -0.77 | -0.68 | 0.68  | -0.24 | 0.24  | 0.37  | -0.37 |
| **Maturity** |
| Bone      | -0.14 | 0.14  | 1.36  | -1.36 | 1.03  | -1.03 | -1.47 | 1.47  | -0.31 | 0.31  | -0.47 | 0.47  |
| Mataram   | -0.85 | 0.85  | -1.13 | 1.13  | 0.50  | -0.50 | 0.40  | -0.40 | 0.77  | -0.77| 0.30  | -0.30 |
| Probolinggo| 0.44  | -0.44 | 0.28  | -0.28 | 1.11  | -1.11 | -0.72 | 0.72  | 1.72  | -1.72| 0.61  | -0.61 |
| Across    | -0.18 | 0.18  | 0.17  | -0.17 | 0.88  | -0.88 | -0.60 | 0.60  | -0.42 | 0.42  | 0.15  | -0.15 |
| **Ear length** |
| Bone      | 0.07  | -0.07 | 0.04  | -0.04 | -0.06 | 0.06  | -0.01 | 0.01  | -0.09 | 0.09  | 0.05  | -0.05 |
| Mataram   | -0.06 | 0.06  | 0.12  | -0.12 | 0.04  | -0.04 | -0.01 | 0.01  | 0.07  | -0.07 | 0.15  | -0.15 |
| Probolinggo| -0.02 | 0.02  | 0.06  | -0.06 | 0.04  | -0.04 | -0.13 | 0.13  | 0.00  | -0.00 | 0.05  | -0.05 |
| Across    | 0.00  | 0.00  | 0.07  | -0.07 | 0.01  | -0.01 | -0.05 | 0.05  | 0.01  | -0.01 | 0.02  | -0.02 |
| **1000 kernel weight** |
| Bone      | 0.18  | -0.18 | 1.07  | -1.07 | -0.08 | 0.08  | -0.13 | 0.13  | -0.40 | 0.40  | -0.63 | 0.63  |
| Mataram   | -0.02 | 0.02  | 1.64  | -1.64 | 0.51  | -0.51 | 0.63  | -0.63 | 0.03  | 0.03  | -0.51 | 0.51  |
| Probolinggo| 0.06  | -0.06 | 0.01  | -0.01 | -0.14 | 0.14  | -0.13 | 0.13  | -0.04 | 0.04  | -0.04 | 0.04  |
| Across    | 0.08  | -0.08 | 0.91  | -0.91 | -0.24 | 0.24  | -0.21 | 0.21  | -0.14 | 0.14  | -0.40 | 0.40  |

Estimates of specific combining ability (SCA) of the 12 F1 crosses for the studied traits under three locations are given in Table 2. Combined analysis of SCA effects showed that most of the F1 crosses had non-significant effects for most of the traits. Falconer and Mackan [12] argued that good GCA effect is obtained from heterogeneous parents such as pools, population, and composite. On the other hand, good GCA is manifested by narrow based (inbred lines) parents upon crossing. Zivanovic et al. [13] indicated that good heterotic response of maize crosses may produce positive and significant SCA.
and higher yield. With respect to days to silking, the crosses MYL 10/MR 14 and MYL 12/MAL 01 showed significant and negative SCA effects whereas MYL7/MAL 01 produced significant and positive SCA effect for ear length. Furthermore, MYL 7/MR14 produced significant and negative SCA effect for ear length. Vacaro et al. [14] reported that higher SCA values is generally derived from hybrids having at least one parental line that having high GCA. The results also indicated that although GCA between inbred and tester is not significantly different, the combination of crossing can produce significant SCA effect. Therefore, in the estimation of SCA effect, the number of location/environment should be taken into consideration. Food crops particularly maize have been more stable across locations than traditional genotypes, buffering ability of hybrids to environmental changes. Therefore, testing on larger number of location and season can reduce the subsequent effect of environments/locations on crossing performance. Thus, the combination of crossing with significant SCA and derived from the inbred or tester with significant GCA can contribute to the improvement of maize performance.

4. Conclusions
The study indicate a wide variability among inbred lines and the possibility to select the preferred inbred lines for hybrid development. Results indicated that inbred line MYL7 had a positive and significant GCA effects for days to silking, maturity, ear diameter. Test cross MYL7× MAL01 for ear length, MYL15× MAL01 for 1000-seed weight, and MYL10 × MR14 for days to silking. The estimates of GCA and its interaction with environments were statistically significant except plant height across locations. GCA variance was larger than SCA variance for days to silking, plant height, maturity and 1000-seed weight indicating that additive gene action played major role than non-additive gene action in the inheritance of the traits. In addition, SCA variance was larger than GCA for ear length indicating that non-additive gene action played major role than additive gene action in the inheritance of the traits.

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