Statistical test for interaction of $G \times E$ on QPM grain yellow for hybrid candidate under lowland in Indonesia

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Abstract. The use of the statistical test has been demonstrated to assess the interaction of single crosses QPM maize genotypes ($G$) under five different environments ($E$). The statistical pooled model used in this study i.e. $y_{ij} = \mu + \tau + \alpha + \epsilon$ and $y_{ij} = \mu + \tau + \alpha + \lambda + (\alpha \times \lambda) + \epsilon$, (effect of mean, replication within the location, entry, interaction gxe, error). The parental material was introduced from CIMMYT Maize Lines (CML) and the yellow grain tester was modified by MR14x CML164 backcrosses programs until BC3F3. The testing environment ($e_i, i=1,2,3,4,5$) were lowland zone in (e1) Maros experimental Farm, (e2) Bajeng, (e3) Bontobili, (e4) Sidondo and (e5) Polman farmers field. Experiments were conducted by a randomized complete block design with three replications. The first variables were analyzed separately in each $e_i$ ($i:1,2,3,4,5$) and followed by pooled analysis by $g_j$ ($j:1,2,3, \ldots, 10$). There were ten variables observed, the grain yield was observed in water content (wc) of 15%. The spacing used was 75x20cm one plant per space, the fertilizer applied were urea-ponska (200-150 kg/ha), weeding and irrigated was regularly conducted for maximum plant growth. The experiments were conducted on the rainy season in 2018. The statistical test showed that there is a significant difference of genotypes under five environments, interaction gxe, and cv: 10.69%, test by LSD (least significant difference) found that two candidates single cross (1)CML161-2-1-4-2xMR14Q and (2)CML165-3-1-2-4xMR14Q were high yielded and significantly different with two check variety MSQ.C0xMR14Q and Bima 13Q. The second single crosses could be promising as new QPM hybrids with yield potential 9.0-10.0 t/ha. The ear position is on the middle of the plant, shelling 75.2-77.8%, flowering 55 days and plant aspect scored one. QPM (Quality Protein Maize/Maize) is defined as speciality maize which has a high content of lysine and tryptophan. These are two essential amino acids that have important nutritional values for the human body to anticipate the disease among children and could be supplemented for human diets.

1. Introduction
Maize is the queen of cereal crops with the highest grain yield potential. One of the staple food in Indonesia, especially in the Eastern part of Indonesia is maize. The Indonesian Cereals Crops Research Institute (Balitsereal) has collected numbers of QPM inbreds introduced from CIMMYT.

Daily protein requirement for average Indian adult is 52g against the availability of merely 26–30g in the daily diet [12]. To alleviate malnutrition, protein content can be increased to as high as 18% by increasing the prolamine (zein) fraction in maize endosperm [4]. Unfortunately, it consequently led to lysine and tryptophan deficiency. Many researchers around the globe have tried to address the problem using quality protein maize (QPM). The advantage of QPM maize is mainly due to the content of lysine (around 0.43%) and tryptophan (0.12% - 0.13%) and higher than that of ordinary maize lysine.
only 0.20% and tryptophan 0.04%. Although QPM protein content is relatively the same as ordinary maize, in the body it can be used 2-3 times compared to ordinary maize because the quality and biological value of the protein is much higher. The protein content of QPM (82%) is much higher compared to regular maize (32%).

Statistical test has been conducted on two factors interaction GxE under evt (evaluation variety trial). There are ten genotypes as single crosses (G) of yellow grain QPM and five of lowland environments (E) under tropical zone in IND. The pooled model were (1) one factor \[ y_i = \mu + \tau + \alpha + \epsilon \] and (2) interaction factors \[ y_{ij} = \mu + \tau/\lambda + \alpha + (\alpha \times \lambda) + \epsilon, \] (effect of mean, replication within environment/location, entry or genotypes, interaction gxe, and error). The genetic material of QPM (Quality Protein Maize) was discovered by Linn Bates in 1963 which identified has high lysine content related to the opaque-2 gene. The opaque-2 mutant still ranks at the top of all viable single mutant, and opaque-2 endosperm also contains a much higher level of tryptophan [6]. The essential amino acid has nutritional values needed to counter the nutritional deficiency (kwashiorkor) on children and to balancing the diets [1].

The objective of the research was to describe the statistical test of the interaction of GxE of candidate single cross hybrids QPM in evt under lowland tropical zone in IND

2. Materials and Methods
All experiments were conducted by RBD with three replication (R). There are ten QPM-Genotypes (Gi, i:1,2,3, ... 10) of yellow grain maize including check Bima 13Q that were evaluated in five environments (Ej, j:1,2,3,4,5) under low land tropical zone in IND (<50 m above the sea). Grain yield grain under 15% wc was predicted by: \[ Y: ((10000/7.5)*(100-wc)/85)*(shelling)*ear weight. \] The shelling data were sampled from five ears [2]. The ANOVA analysis for grain yield was analyzed by two factors interaction (GxE) [10], [9], [14]. Genotypes were planted in four rows with the spacing of 75x20 cm one seed per hole 5.0 m length, the fertilizer applied were Urea and Ponska (300-200 kg/ha), watering was done every 7-10 days. The parent materials of QPM (CML161, CML165, CML170, CML172) were imported from CIMMYT, El Batan Mexico on 2002, and MSQ(S1) was the result of ICERI recombination of yellow grain CML (CML161-CML172) on the cycle of zero [11]. The single cross was selected under the light table which has opaque color. EVT were conducted in Maros experimental farm, Bajeng, Bontobili, Sidondo and Polman farmers field (e1,e2,e3,e4,e5). The data collected were vegetative plant characters, ear height, tasseling, the component of the generative stage, and soil characteristics. The ICERI program for evt was conducted on rainy season February-May on 2018.

3. Results and Discussion
3.1. Yield Variable
The analysis result of all variable observed was shown in table 1. and there are highly significant interaction of yield, flowering, shelling, and water content (Table 1). The yield shown that CML161-2-1-4-2 x tester (MR14Q), CML170-1xtester, MSQ(S1)C0-26-1-1xtester, and MSQ(S1)C0-43-1-1-1xtester were significantly different compared to check Bima 13Q. This single cross that has the highest yield and potential to be released as a new hybrid variety is CML161-2-1-4-2xMR14Q. In table 1. we can see that single factor was also significant in plant height, flowering, shelling, lines number per cob, number of seeds per cob, and water content.
Table 1. The statistical analysis of the variable of the single cross QPM candidate

| Variable            | df   | E          | R/E       | G          | E x G       | Error      | CV (%) |
|---------------------|------|------------|-----------|------------|-------------|------------|--------|
| Yield               |      | 86.803     | 0.436     | 3.164**    | 1.571**     | 0.726      | 10.68  |
| Plant height        |      | 19,536.264** | 310.048   | 366.256**  | 136.729**   | 172.216    | 6.03   |
| Ear height          |      | 10,110.140** | 87.513    | 140.347**  | 72.903**    | 117.903    | 10.46  |
| Flowering           |      | 133.657**  | 5.867     | 17.292**   | 5.331**     | 3.452      | 3.32   |
| Shelling            |      | 7.538ns    | 5.750     | 15.193**   | 6.006ns     | 6.495      | 3.29   |
| Lines number        |      | 25.867**   | 1.647     | 2.630**    | 1.053ns     | 1.499      | 9.78   |
| Seeds no./line      |      | 63.814**   | 14.545    | 23.394**   | 20.171**    | 16.369     | 12.58  |
| Seeds no./cob       |      | 25.867**   | 1.787     | 2.726**    | 1.185ns     | 1.520      | 9.84   |
| Water content       |      | 424.490**  | 2.176     | 32.753**   | 5.325**     | 2.505      | 5.56   |
| Weight 1000 seeds   |      | 23,985.876** | 131.521   | 428.779**  | 763.107**   | 390.197    | 6.27   |

ns : not significant
*: significant in level 95%
**: highly significant in level 99%

The CV for the yield was <20.0% and it is assumed that it could be selected for Gi, i = 1, 2, 3, . . , 9 for new F1 maize varieties. The population of yellow grain maize from CIMMYT were adapted in Maros after selected by S1 families and genetically improved by one cycles of selection, yielded 8.0-10.0 t/ha [15].

Table 2. Grain yield of candidate QPM hybrid, rainy season evt. 2018

| Genotype            | Maros   | Bajeng   | Bontobili | Polman    | Sidondo** | Mean    |
|---------------------|---------|----------|-----------|-----------|-----------|---------|
| 1. CML161-2-1-4-x   | 9.32**  | 10.80**  | 6.47**    | 10.03**   | 7.61      | 8.85**  |
| 2. CML165-3-1-2-4-x | 8.76    | 9.64**   | 5.54*     | 9.52      | 7.01      | 8.09*   |
| 3. CML170-1-x       | 9.71**  | 8.22     | 5.49*     | 10.20**   | 7.63      | 8.27*   |
| 4. CML172-2-1-2-x   | 7.67    | 8.12     | 5.73*     | 9.54**    | 7.56      | 7.72    |
| 5. MSQ(S1)C0-26-1-1-x| 9.12*   | 8.33     | 5.28      | 10.95     | 6.63      | 8.06*   |
| 6. MSQ(S1)C0-27-1-1-x| 8.21    | 7.61     | 5.46      | 10.26**   | 6.17      | 7.54    |
| 7. MSQ(S1)C0-34-1-x | 7.72    | 8.59     | 5.80**    | 10.40**   | 6.55      | 7.83    |
| 8. MSQ(S1)C0-43-1-1-1-x| 8.31    | 8.74     | 5.21      | 10.66*    | 7.44      | 8.07*   |
| 9. MSQ.C0 x         | 8.32    | 9.50     | 5.05      | 10.26**   | 7.78      | 8.18*   |
| 10. Chek (Bima 13Q) | 7.54    | 7.91     | 4.54      | 7.46      | 8.27      | 7.14    |

Mean : 8.47        8.75 | 5.46 | 9.94 | 7.27 | 8.85
CV (%) : 9.52 | 11.30 | 9.93 | 9.90 | 11.89 | 9.06
LSD 5% : 1.38 | 1.69 | 0.93 | 2.10 | 2.87 | 0.885
LSD 1% : 1.89 | 2.87 | 1.27 | 2.87 | 2.10 | 1.219

**: significantly different in level 95% to check (Bima 13Q)
*: highly significantly different in level 99% to check (Bima 13Q)
ns : not significant to check (Bima 13Q)

Table 2 shows that on average in three replication, the highest grain yield (under 15% water content) was obtained by CML161-2-1-4-xMR14Q, in Polman the productivities were 10.03 t/ha and the average on five locations was 8.85 t/ha. The candidate was yielded 24.10% higher than check Bima 13Q and significantly different on e1, e2, e3, and e4 (maros, bajeng, bontobili and polman), in e5 (Sidondo) the candidate has a lower yield than check (Bima 13Q).

3.2. Agronomic Variables.

The observed agronomic characters and statistical analysis by LSD and coefficient of variation (CV) of plant and ear height, tasseling, flowering/silking, the water content of grains, the weight of 1000 grains, and visual observed by plant aspect were shown in table 3. The plant height significantly differed under rainy season as shown in table 3. There are six F1 that were significantly different from the check. The agronomic characters of the single cross namely ear height, tasseling and silking periods and water content were similar to check Bima 13Q. Plant aspect scored <2.0
Weight of 1000 grains of the candidate was not significantly different from the check. The CML161-2-1-4-2 x tester which has the best result showed the ear height characteristics on the middle of the plant and this character was selected for superior plant and anthesis silking interval (asi) were less than three days. Asi was different of silking and tasseling period, the value asi >5.0 days was not selected. Variable of asi (anthesis silking interval) shown that the range of silking and tasseling periods were 2.0-4.0 days. The value of asi<3.0 days was very synchronized for the optimum number of seeds generation. Djamaluddin and Yasin [3], reported that generation F1 on functional maize with asi of 3-4 days and yield of 8-9 t/ha 15% wc. of grain. The yield of MS-2 lines maize with asi about 5-6 days was 2-3 t/ha [5].

4. Conclusion
Some of the factors of GxE were highly significantly different under five environments in a lowland tropical zone. The best result was obtained by single cross CML161-2-1-4-2 x MR14Q with the productivity of 10.03 t/ha and average of 8.85 t/ha on five locations. The Candidate has 24.10% higher yield than check Bima 13Q and significant different on e1, e2, e3, and e4 (maros, bajeng, bontobili and polman), but in e5 (Sidondo) the candidate has lower yield than check (Bima 13Q).

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