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Combining ability analyses of grain yield and kernel micronutrient content in maize (*Zea mays*)

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ABSTRACT

The present study was aimed to assess the general combining ability of parents and specific combining ability of their crosses for yield and yield related traits. Nine inbred lines were crossed with two testers using line × tester mating design. Nine lines, two testers and 18 experimental hybrids were evaluated along with two checks in this study for grain yield and protein content, besides kernel micronutrients (phosphorous, caicium and iron) during *kharif* 2019 in a randomized block design at experimental farm of BAC, Sabour. The line CLQRCY44 and HKI1532 were found as good general combiner for grain yield and quality traits followed by DHOLI inbred 55 and CLO2450. Lines DHOLI inbred 55 and CML451 were found as good general combiner for earliness, lines CLQRCY44, CLO2450 and DHOLI 55 for quality traits like protein content, calcium content, phosphorous and iron content. Among the crosses, HKI1532 × 95IOWA (67.43 q/ha), LM13 × SUWAN (65.87 q/ha) and CML425 × SUWAN (63.30 q/ha) were the promising crosses for grain yield. CLO2450 × SUWAN and LM13 × SUWAN exhibited highly significant and desirable SCA effects for grain yield. CLO2450 × 95IOWA exhibited highly significant and desirable SCA effects for protein content. HKI1532 × 95IOWA (67.43 q/ha) was the promising hybrid for grain yield and micronutrient content. Therefore, these crosses can be utilized for developing high yielding micronutrient enriched hybrid varieties in maize (Zea mays L).

Keywords: Combining ability, Kernel microutrient, Line × Tester

Maize (*Zea mays* L) is considered as one of the major cereals in the world. Currently, nearly 1147.7 million MT of maize is being produced together by over 170 countries from an area of 193.7 million ha with an average productivity of 5.75 t/ha. Among the maize growing countries, India ranks 4th in area and 7th in production, this is around 4% of world maize area and 2% of total production. During 2018-19 in India, the maize area has reached to 9.2 million ha. Maize provides a large proportion of the daily intake of energy and other nutrients, including micronutrients for poor populations in many areas of South East Asia and sub-Saharan Africa. However, most of the staple food crops including maize display very low concentration of such micronutrients, especially P, Fe and Ca. To combat this problem of 'hidden hunger', plant breeding techniques are now being emphasized to develop genotypes of staple foods whose edible portions are denser in bioavailable minerals and vitamins, a process referred to as 'biofortification. Improving the nutritional quality, especially for micronutrients, is now an important breeding goal in maize, particularly for kernel Fe and Zn concentrations and β-carotene (Pfeiffer and McClafferty 2007). To breed high yielding crops with improved quality, evaluation of genetic variability for the target traits, besides grain yield and its components, is the first important step. The concept of combining ability analysis plays a significant role in crop improvement as it helps in characterizing the nature and magnitude of genetic effects governing yield and its component traits besides pin pointing the promising parents to be used in the synthesis of superior hybrids and populations, particularly when the production of hybrids is not feasible due to some inherent problems in economic hybrid seed production. Many researchers have reported on the combining ability for grain yield of maize (Kanagarasu *et. al.* 2010, Amiruzzaman *et al*. 2011, Premlatha *et al.* 2011, Abuali *et al*. 2012, Krupakar *et. al*. 2014, Mohammad *et al*. 2016, Dar *et al*. 2017, Tulu *et al*. 2018). This emphasizes the importance of combining ability analysis. The present study was undertaken with a view to estimate general combining ability of parents and specific combining ability of their crosses for yield and kernel micronutrient concentrations.

MATERIALS AND METHODS

The materials consisted of a set of 31 genotypes, including 9 lines (HKI1105, CML425, CLQRCY44 , LM13, HKI1532, DHOLI Inbred 55, CLO2450, VQL 1, CML451), two testers (95IOWA and SUWAN), eighteen experimental hybrid combinations and two commercial checks (Birsa

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Vikas Makka 2 and Sabour Hybrid Maize 1). Eighteen crosses were obtained from the set of parents using the methodology of line × tester mating design during *rabi* 2018-19. The 11 parents and 18 experimental hybrids along with the two checks were evaluated at Bihar Agricultural College, Sabour, BAU, experimental farm during *kharif* 2019. The materials were planted in randomized block design (RBD) with three replications per entry and two row per replication and with a plant-to-plant spacing of 20 cm and row-to-row spacing of 60 cm. Standard agronomic practices were followed for raising and maintenance of the plants. Five random plants from each row were selfed and the rest were allowed to open-pollinate. For kernel micronutrient analysis, only the selfed ears were hand-harvested. Except for the traits for which data were recorded on standing crops in plots, data for yield components were recorded on ears from five randomly sampled open pollinated plants or on five randomly sampled open pollinated ears, as applicable to the case. Observations on various traits, viz. grain yield, protein content, calcium content, phosphorous content, iron content were recorded on five randomly selected competitive plants except for maturity traits (days to 50% tasseling and days to 50% silking on plot basis). Data was subjected to ANOVA to detect the significance of genotypic differences. Combining ability analysis was carried out and data was analysed using Indostat software. Biochemical traits like protein content (Micro Kjeldahl method), phosphorous content (spectrophotometer), iron content (atomic absorption spectrophotometer), calcium content (flame photometer) were calculated for all the 31 genotypes.

RESULTS AND DISCUSSION

Perusal of the results revealed significant differences among parents lines, crosses and line × testers for all traits under study, indicating that the materials selected were diverse for all the traits under study. Significant L×T component suggested presence of high SCA among hybrids. It was also found that mean squares due to lines were larger when compared to testers for all the traits indicating greater diversity among lines.

This was in confirmation with the results reported by Abuali *et al*. (2012). Analysis of variance for combining ability revealed significant mean squares for GCA and SCA for all the traits studied which indicated importance of both additive and non-additive gene action in the inheritance of these traits. The knowledge of combining ability effects of parents and crosses together with per se performance is of paramount importance to a breeder for isolating desirable lines and selection of an appropriate methodology for handling the segregating generations. The general and specific combining ability of the parents and crosses respectively were estimated and discussed below:

General combining ability effects: The GCA effects represent the additive nature of the gene action. In the present study, the general combining ability of parents (9 lines and 2 testers) were estimated to know their genetic worth for use in production of superior progenies (Table 1).

The close examination of the results revealed that parents L_3, L_5 and L_6 showed high positive GCA effects for grain yield. All lines except L_7 had significant GCA effects for protein content. Similarly all lines and tester were identified good for calcium content. Although line L_3 showed significant GCA effect in the desired direction simultaneously for grain yield and all the quality traits. It was revealed from the experiment that L_3 was identified as best general combiner followed by L_5, L_6, L_2, and L_4.

Table 1 Estimates of GCA effect of parents

Parent	Grain yield (q/ha)	Protein content (%)	Calcium content (mg/100 g)	Phosphorous content (mg/100 g)	Iron content (mg/100 g)
L_1	-1.20	-0.58 ***	-0.57 ***	-1.15 ***	-212.41 ***
L_2	-1.34	0.49 ***	1.12 ***	-19.65 ***	75.92 ***
L_3	6.06 **	0.94 ***	0.24 ***	7.02 ***	229.26 ***
L_4	-4.83 **	0.25 ***	-0.71 ***	2.85 ***	55.93 **
L_5	2.84	0.56 ***	0.93 ***	0.52	32.59 *
L_6	2.30	0.52 ***	-0.82 ***	3.52 ***	305.93 ***
L_7	2.21	-0.02	1.23 ***	15.35 ***	-122.41 ***
L_8	-3.69 *	-0.43 ***	-1.13 ***	-0.15	-547.41 ***
L_9	-2.41	-0.74 ***	-0.28 ***	-8.32 ***	182.59 ***
T_1	1.60	0.09 ***	-0.32 ***	-2.82 ***	57.96 ***
T_2	-1.60	-0.09 ***	0.32 ***	2.82 ***	-57.96 ***
CD @ 5% (Line)	1.75	0.05	0.05	0.27	15.63
CD @ 5% (Tester)	0.83	0.02	0.02	0.13	7.37

*Significant at 5% level of significance; ** Significant at 1% level of significance; *** Significant at 0.1% level of significance (L_1: HKI 1105, L_2: CML425, L_3: CLQRCY44, L_4: LM13, L_5: HKI 1532, L_6: DHOLI Inbred 55, L_7: CLO2450, L_8: VQL 1, L_9: CML451, T_1:95 IOWA, T_2: SUWAN)

Table 2 Estimates of SCA effect of crosses

Cross	Grain yield (q/ha)	Protein content (%)	Calcium content (mg/100 g)	Phosphorous content (mg/100 gm)	Iron content (mg/100 g)
$L_1 \times T_1$	-3.05	0.51***	-0.58 ***	-3.19***	-37.96
$L_2 \times T_1$	3.05	-0.51***	0.58 ***	3.19 ***	37.96
$L_3 \times T_1$	0.10	-0.04	-0.64 ***	18.98***	-152.96***
$L_4 \times T_1$	-0.10	0.04	0.64 ***	-18.98***	152.96 ***
$L_5 \times T_1$	4.47	0.10	2.48 ***	19.98 ***	380.37 ***
$L_6 \times T_1$	-4.47	-0.10	-2.48 ***	-19.98***	-380.37***
$L_7 \times T_1$	-0.25	0.53***	-0.78 ***	-19.52***	-16.30
$L_8 \times T_1$	0.25	-0.53***	0.78 ***	19.52***	16.30
$L_9 \times T_1$	-4.96	0.38***	1.07 ***	-1.52 ***	-109.63***
$L_1 \times T_2$	4.96	-0.38***	-1.07 ***	1.52 ***	109.63 ***
$L_2 \times T_2$	4.10	-0.46 ***	-0.67 ***	4.15 ***	280.37 ***
$L_3 \times T_2$	-4.10	0.46 ***	0.67 ***	-4.15 ***	-280.37 ***
$L_4 \times T_2$	6.77 **	-0.14 *	-0.62 ***	-7.68 ***	-451.30 ***
$L_5 \times T_2$	-6.77 **	0.14 *	0.62 ***	7.68 ***	451.30 ***
$L_6 \times T_2$	-7.77 **	-0.35***	-0.15 *	-12.18***	-22.96
$L_7 \times T_2$	7.77 **	0.35***	0.15 *	12.18***	22.96
$L_8 \times T_2$	0.60	-0.53***	-0.12	0.98 *	130.37 ***
$L_9 \times T_2$	-0.60	0.53***	0.12	-0.98 *	-130.37 ***
CD (P=0.05)	2.47	0.07	0.07	0.38	22.11

* Significant at 5% level of significance; ** Significant at 1% level of significance; *** Significant at 0.1% level of significance

These can be used directly as parents for developing high yielding single cross hybrids having good quality traits. All the lines were accompanied with significant gca for protein, calcium, phosphorous, iron content. Similar results were reported for yield and yield related traits by Pavan *et al.* (2011), Khan *et al.* (2014), Alamerew and Warsi (2015) and Gemechu and Abu (2020).

Specific combining ability effects: The estimates of specific combining ability effects of the eighteen crosses for various traits are given in Table 2.

The cross combination $L_7 \times T_2$ possessed high SCA effects for grain yield and other quality traits except iron content. However, crosses which exhibited highly significant and desirable SCA effects were $L_7 \times T_2$ and $L_4 \times T_2$ for grain yield, crosses $L_1 \times T_1$, $L_7 \times T_1$, $L_9 \times T_1$, $L_3 \times T_2$, $L_5 \times T_2$, $L_7 \times T_2$ and $L_9 \times T_2$ for protein content, $L_2 \times T_1$, $L_4 \times T_1$, $L_5 \times T_1$, $L_8 \times T_1$, $L_9 \times T_1$, $L_3 \times T_2$, $L_5 \times T_2$ and $L_7 \times T_2$ for calcium content crosses $L_2 \times T_1$, $L_3 \times T_1$, $L_5 \times T_1$, $L_8 \times T_1$, $L_1 \times T_2$, $L_2 \times T_2$, $L_5 \times T_2$, $L_7 \times T_2$ and $L_8 \times T_2$ for phosphorous content and crosses $L_4 \times T_1$, $L_5 \times T_1$, $L_1 \times T_2$, $L_2 \times T_2$, $L_5 \times T_2$, and $L_8 \times T_2$ for iron content. The cross combination $L_5 \times T_2$ exhibited significant positive SCA effect for all the quality traits like protein content, calcium content, phosphorous content and iron content. Many researchers reported significant positive and negative SCA for grain yield (Girma *et al.* 2015, Ram *et. al.* 2015).While assessing the performance of parents on the basis general combining ability, it was observed that most of the specific cross combinations were the result of crosses between low × high or low × low or low × medium or high × high or high × medium general combiners. Among crosses, $L_1 \times T_2$ showed the higher positive SCA effect for yield had medium × high combiners; $L_7 \times T_2$ had high × high combiners; $L_4 \times T_2$ had low × high combiners suggesting that involvement of one good general combiner appears to be essential to get the better specific combination. The results are in general agreement with the findings of Dar *et al.* (2017). Manifestation of high SCA effects in some cross combinations results due to accumulation and interaction of favorable alleles from parents that are high or medium general combiners. Thus the superiority of crosses involving high × high and high × medium combiners as parents might have possibly resulted from the concentration and interaction of favourable alleles contributed by parents. The case of high SCA between high × low combiners could produce good segregants only if the additive genetic effects are present in the good general combiners and complementary epistatic effects in the poor combiners and they act in the same direction to maximize desirable plant attributes. The high yield of such crosses would be nonfixable and thus could be exploited through heterosis breeding. The superior cross combination involving low × low combiners could result from over-dominance and/or epistasis. It can be concluded that the highly significant differences were observed among line and line × testers for all the traits which indicate the possibility of selection for improvement of yield and quality traits. Among parents, L_3, L_5 and L_6 showed highly desirable GCA effects for grain yield. Line L_3 showed significant GCA effect in the desired direction simultaneously for grain yield and all the quality traits. Identified inbred lines with desirable positive GCA effects for grain yield and other traits will be used for breeding to develop hybrid. The same recommendation was given by Gemechu and Abu (2020). Moreover, crosses $L_7 \times T_2$ and $L_4 \times T_2$ possessed high SCA effects for grain yield. $L_5 \times T_2$ reflected high SCA effects for all the quality traits. The cross $L_7 \times T_2$ possessed high SCA effects for grain yield and quality traits. Thus these crosses can be used directly or exploited for future hybrid breeding programmes to achieve quantum jump in maize improvement.

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