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Heterosis and combining ability studies in maize (*Zea mays* L.)

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Maize (*Zea mays* L.) is one of the important food and forage crops with abundant natural diversity. The exploitation of heterosis is possible only when the parents involved in the crosses differ in their combining ability. Generally high heterosis values are desirable for grain yield in maize. The combining ability analysis facilitates the partitioning of genotypic variation of the hybrids into variation due to general combining ability (main effects) and specific combining ability (interactions), which indicates about a measure of additive and non-additive gene action. For exploiting hybrid vigour, *per se* performance, *sca* effects and the extent of heterosis of hybrids are important.

Maize is the third most important cereal next to wheat and rice in both area and productivity. India occupies an area of 7,400,000 ha with an average productivity of 1,959 kg/ha. (FAO, 2004). Maize is used as human food, animal feed and industrial raw material. The grain is used for food and feed for cattle and poultry. Green leaves, stems are used as fodder for cattle. Grain is also used to produce starch, corn oil, syrups, beverages, vitamins and amino acids. Maize oil is used as cooking oil. It is also used with linseed oil for paints. Maize is a highly cross pollinated crop and the scope for the exploitation of hybrid vigour will depend on the direction and magnitude of heterosis, biological feasibility and the type of gene action involved. The exploitation of heterosis is possible only when the parents involved in the crosses differ in their combining ability. An attempt has been made to review the available literature relevant to heterosis and combining ability in maize.

Heterosis:

Heterosis is defined as the percentage of hybrid over the parental mean and generally high heterosis values are desirable for grain yield in maize.

Gupta *et al*. (1994) reported that 16 out of 23 double cross hybrids showed high degree of heterosis for grain yield than the best standard. Shweta Kumar (1995) reported that eight out of 25 hybrids showed high degree of heterosis for grain yield per plant and earliness. Nagda *et al*. (1995) studied 20 F_1 hybrids and reported that 15 crosses exhibited significant positive heterosis for grain yield over best check and revealed significant negative heterosis for days to silking, plant height and ear height in all crosses except one cross. Ling *et al*. (1996) confirmed that mean heterotic effect was the highest for grain yield per plant followed by grain weight and ear thickness. Saha and Mukherjee (1996) reported that there was significant positive heterosis for grains per ear and the crosses with highest heterosis for 100-grain weight and grain yield per plant had high negative heterosis for percentage grain conversion. Ling *et al.* (1999) noted that the 100-grain weight of all hybrids was greater than the female parents. But heterosis of mid parental value differed according to the relative grain weight of parents. Nagesh Kumar *et al*. (1999) observed heterosis for grain yield which ranged from 26.31 to 37.30 per cent over better parent. Chiduaa *et al*. (1999) reported a high degree of heterosis for grain yield in the hybrids, Stojokovic *et al*. (1999) reported that the partial or complete dominance of dominant alleles with additive effects were the main contributors to yield heterosis in maize. Netaji *et al*. (2000) observed significant and positive heterosis and heterobeltiosis for grain yield in more than 20 hybrids and expression of heterobeltiosis was most evident for grain yield per plot, followed by test weight, ear length, ear height, plant height and number of seed rows per ear. Shahwani *et al.* (2001) noticed positive and significant heterosis in 17 hybrids, while 11 hybrids showed heterobeltiosis for ears per plant. Saleh *et al.* (2002) reported high estimates of heterosis for grain yield, ear weight, grain weight per ear, moderate estimates for plant and ear height, shelling percentage, ear diameter, number of kernel rows per ear, number of kernels per ear row and grain weight. Singh (2003) reported highly significant negative heterobeltiosis and standard heterosis for early silking.

Combining ability and gene action:

The combining ability analysis facilitates the partitioning of genotypic variation of the hybrids into

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variation due to general combining ability (main effects) and specific combining ability (interactions), which indicates about a measure of additive and non-additive gene action. High general combining ability effect for a particular trait in a parent indicates the presence of additive gene effects for that trait in the concerned parent. Hence, the *gca* has an important role in selection of parents for hybridization programme.

Satyanarayana *et al*. (1995) reported that both additive and non-additive gene effects were important for days to 50 per cent tasseling and yield. Mohammed (1995) observed that genetic variances for ear length and number of ears per plant were mainly additive, while plant height, ear weight, grain weight per ear, 100-grain weight and yield were non-additive. Beck *et al*. (1995) concluded that general combining ability was significant for plant height, ear height, days to silking and yield, while specific combining ability was significant for ear height, days to silking and yield. Ling *et al*. (1996) reported that grain yield per plant exhibited epistasis. Additive gene action appeared to be more important for ear thickness and kernel rows per ear. Inheritance of ear length, 100-grain weight and grain yield per plant was controlled by dominant and epistatic effects. For ear thickness, recessive genes had positive effects and dominant genes had negative effects and for other characters the gene effects were vice versa.

Preciado *et al*. (1997) observed that general combining ability and specific combining ability were significant for yield, days to silking and grain filling period. Mathur *et al*. (1998) reported that there was a significant GCA variance for days to silking, ear length, ear girth, number of rows per ear, number of grains per row and grain yield per plant. The SCA variance was significant for ear length. Singh and Singh (1998) indicated that GCA was more important for ear length and number of kernels per row and SCA was more important for grain yield per plant, ear diameter, number of kernels per ear, 100-grain weight, days to silking, plant height and ear height. Joshi *et al*. (1998) reported that there was preponderance of non-additive gene action in the expression of yield per plant, protein and starch content, while for oil content and 100-grain weight there was preponderance of additive gene action. Altinbass and Tosan (1998) concluded that the results of GCA and SCA variances for grain yield per plant and other traits indicated that screening parental lines and crosses using combining ability effects for 100 grain weight and ear length would be effective. Konak *et al*. (1999) reported that higher SCA variances were noted for grain yield, 1000-grain weight, ear height, ear length and earliness. Higher GCA variances were noted for plant height and number of rows per ear. Kumar *et al*. (1999) reported that non-additive gene action was predominant for grain yield and yield component characters. Solilman and Sadek (1999) reported higher positive and significant *gca* effects for grain yield. Talleci and Kochaksaraci (1999) observed significant *gca* effects for plant height, ear height, days to silking, days to tasseling, kernel length, yield per plant and stomata number. Geetha and Jayaraman (2000) reported that additive and dominance components were significant for plant height, number of grain rows per cob, number of grains per row, cob weight, 100-grain weight and grain yield. Kara (2001) observed significant *gca* effects for all the traits and significant *sca* effects for ear diameter, ear height and grain yield per unit area. Kalla *et al*. (2001) found additive and non additive gene actions important for 1000-grain weight, kernel rows per cob, grains per cob, cob girth, cob length and grain yield per plant. They also reported significant and positive *sca* effects for grain yield per plant.

Konak *et al*. (2001) obtained non-additive gene effects for ear length and number of rows on ear and additive gene effect for yield, 1000-kernel weight, plant height, ear height and days to silking. Mahto and Ganguly (2001) observed that both additive and non-additive genetic components for 100-grain weight and shelling percentage in CML 85 and CML 89. The crosses showed positive and highly significant specific combining ability effects for grain yield. Vacaro *et al*. (2002) reported that mean square for *gca* effects was greater than that for *sca* effects for the traits like plant height, point of insertion of the first ear, number of ears per plant, number of grains per ear, root and stalk lodging and grain yield indicating the performance of additive gene effects. Aurelio *et al*. (2003) found that both additive and non additive gene effects were important for grain yield. While for other traits additive gene effects were more important. Betrain *et al*. (2003) found that the specific combining ability for grain yield was significant. Prasad and Pramod Kumar (2003) reported that highly significant *gca* effects for number of kernel rows per ear, number of kernels per row and grain yield and high *sca* effects for grain yield, ear length, ear girth and 1000-kernel weight. They also reported the non-additive gene action for plant height, ear height, ear length, ear girth, kernel rows, number of kernels per row, 1000-kernel weight and grain yield.

Singh (2003) reported significant positive specific combining ability for grain yield, days to silking and maturity. Aydin Unay *et al*. (2004) studied that general and specific combining ability effects were significantly different for grain yield among parents. The grain yield was under the dominance gene effect. Alexander Pswarayi and Bindiganavile Vivek (2004) studied early maturity maize varieties across seven South African countries and they found good *gca* effects for grain yield. Rezaci and Roohi (2004) studied a complete set of diallel crosses among ten corn inbred lines and found that additive and non additive genetic components were significant for grain yield, days to tasseling, plant height and ear height. Singh (2004) reported that highly significant *gca* effect for 100-kernel weight and ear length and significantly negative *sca* effects for days to silking and maturity. They also found non-additive gene action of grain yield. According to Katna *et al.* (2005) both the *gca* and *sca* effects were significant for leaf area per plant, plant height, ear height, ear length, ear circumference, kernel rows per ear, kernels per row, 100-seed weight and grain yield per plant. They also reported preponderance of additive gene effects was important in the expression of all the above traits.

Quality characters:

Kumar and Kumar (2000) found that the oil content was high in late maturing and dwarf plant types with lower number of seed rows and seeds per ear in addition to lower 100-seed weight. Pramod Kumar *et al.* (2003) reported that heterosis over mid parent varied from 16.67 to 140.59 and better parent varied from 23.57 to 137.10 for oil content of maize.

Dodiya and Joshi (2003) observed the predominant role of non-additive type of genetic component in the inheritance of oil and protein content. They also found some of the hybrids were good specific combiners with high heterosis for oil and protein content along with high yield potentials. Pramod Kumar *et al.* (2004) reported that highly significant GCA and SCA variances for oil content. They also found additive and non-additive gene action for oil content and the crosses showing high *sca* effects also exhibited high heterotic values. Joshi *et al.* (1998) reported that there was preponderance of additive gene action for protein content and 100-seed weight.

Conclusion:

For exploiting hybrid vigour, *per se* performance, *sca* effects and the extent of heterosis of hybrids are important. Selection based on any one of these criteria alone may not be effective. The hybrids with high *per se* performance need not always reveal high *sca* effect and *vice versa*. So selection must be based on all the three parameters.

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