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Combining ability for maize inbreds lines for yield and yield traits

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Abstract
Analysis of variance showed that mean squares were highly significant for traits such as number of kernel rows per ear, number of kernels per row, number of kernels per ear, 100 kernel weight (g), kernel weight per ear (g), kernel yield per plant (g). etc. High heritability coupled with high genetic advance was recorded for the traits plant height and ear height that depicts the existence of additive gene effects. The analysis of variance for combining ability revealed that mean squares were significant for almost all the characters. Variance due to *sca* was greater than *gca* variance for the traits viz., plant height, ear height, number of kernels row/cob, number of kernels/row, ear length, cob yield and grain yield, which indicated the preponderance of non-additive gene effects in the genetic expression of these traits. The parents/inbred lines 52099, DS-NP/R-8-42 and IC-280427 were found good general combiner. Experimental hybrids obtained with high specific combining ability (SCA) effect were DML-1336 x DS-NP/R-8-42, 52099 x DML-1336, 52327 x 52099 and 52212 x DML-1112.

Keywords: GCA, SCA, yield, hybrid vigor and maize

Introduction
Maize, scientifically known as *Zea mays*, stands as one of the most extensively cultivated cereal grains worldwide, celebrated for its adaptability and nutritional significance. Originating from the Americas, maize has served as a fundamental crop for millennia, acting as a dietary cornerstone for civilizations such as the Mayans, Aztecs, and various Native American tribes (Sarvari and Pepo, 2014) [18]. Today, it occupies a pivotal role in agriculture, playing a vital part in sustaining both human and livestock populations globally. Characterized by towering, grassy stalks adorned with large, broad leaves and distinctive tassel-like flowers known as inflorescences (Shao *et al.*, 2021) [19], maize exhibits its kernels in rows on cylindrical cobs, displaying a spectrum of colors from yellow and white to blue and purple. This diversity enables a wide range of culinary applications. With its abundance in carbohydrates, fiber, vitamins, and minerals, maize significantly contributes to global food security (Erenstein *et al*., 2022) [6] and serves as a crucial source of sustenance in various forms, including cornmeal, cornflour, corn oil, and as a whole grain.
Among the countries cultivating maize, India holds the 4th position in terms of area and the 7th in production, representing approximately 4% of the world's maize area and 2% of total production. The primary maize-growing states contributing more than 80% of the total production include Andhra Pradesh (20.9%), Karnataka (16.5%), Rajasthan (9.9%), Maharashtra (9.1%), Bihar (8.9%), Uttar Pradesh (6.1%), Madhya Pradesh (5.7%), and Himachal Pradesh (4.4%). Despite these production levels, amidst a burgeoning population and the challenges posed by climate change (Malhi *et al*., 2021) [13], enhancing maize yield remains a primary focus. Historically, the exploitation of heterosis for yield traits in India has received insufficient attention (Li *et al*., 2021) [12]. Hence, the current study aims to unlock the heterosis potential for grain yield by developing and identifying single-cross hybrids in maize.

Materials and Methods
A set of eight inbred lines were crossed in full diallel mating design (Griffing, Model-I, Method-I) (Griffing, 1956) [9] during *Rabi* 2019 to generate 56 full-diallel crosses

(reciprocals included). The final evaluation trial comprising of eight parents, fifty six F1's (direct and reciprocals) and two standard checks was conducted in *rabi*, 2019 with two replications in randomized block design at research farm of All India Coordinated Research Project on Maize, Rahuri center, at Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar, on a uniform piece of land. All the standard package of practices was followed to raise a good crop. The data were recorded on, days to 50 percent tasseling, days to 50 percent silking, days to maturity, plant height (cm), earhead height (cm), number of nodes per plant, number of leaves per plant, number of ears per plant, ear length (cm), ear girth (cm), number of kernel rows per ear, number of kernel per row, number of kernel per ear, 100 kernel weight(g), kernel weight per ear (g), kernel yield per plant (g), kernel color and kernel shape. Heterobeltiosis was estimated following Fonseca and Patterson (1968) [7].

Results and Discussion

The specific combining ability is primarily a measure non-additive genetic components which suggests for utilizing them in hybrid breeding program. A critical examination of the relative magnitude of GCA and SCA variance and GCA and SCA effects of the parents and crosses helps to plan suitable breeding methodology as high yielding genotype may or may not always transmit its superiority to its progenies. Therefore, the success of a breeding programme is determined by useful gene combinations in the resulting progenies.

In the current investigation, for yield-related traits across three environments, including the number of kernel rows per ear, number of kernels per row, number of kernels per ear, 100-kernel weight (g), kernel weight per ear (g) and kernel yield per plant (g). The outcomes for each trait are comprehensively presented and discussed below.

A. Number of kernel rows per ear

In Environment-1, among the parent varieties, three parents exhibited good general combining ability (GCA) for the number of kernel rows per ear. These parents were DS-NP/R-8-42 (GCA effect: 0.444), IC-280427 (GCA effect: 0.264), and 52099 (GCA effect: 0.219), all showing significantly positive effects. Conversely, three parents, namely 52327 (GCA effect:-0.527), 52212 (GCA effect:-0.217), and DML-1336 (GCA effect:-0.214), exhibited significantly negative GCA effects for this trait.

The hybrid cross IC-280427 x DS-NP/R-8-42 (SCA effect: 1.064) demonstrated the highest significant positive specific combining ability (SCA) effect for this trait. This was followed by DML-1336 x DS-NP/R-8-42 (SCA effect: 0.940) and 52099 x DML-1112 (SCA effect: 0.794). While three crosses displayed significantly positive SCA effects, three other crosses exhibited significant negative SCA effects, ranging from-0.796 (DS-NP/R-8-42 x DML-1112) to-0.6 (DML-1336 x IC-331144).

Among the crosses, DS-NP/R-8-42 x DML-1336 (RCA effect: 1.775) exhibited the highest significant positive reciprocal combining ability (RCA) effect, followed by 52212 x 52099 (RCA effect: 1.615), DS-NP/R-8-42 x 52099 (RCA effect: 1.275), and IC-331144 x 52212 (RCA effect: 1.222). On the other hand, the cross DS-NP/R-8-42 x 52212 (RCA effect: 0.580) had the lowest significant positive RCA effect for this trait. Out of the twenty-eight reciprocal crosses, four crosses demonstrated highly significant and positive RCA effects, while three crosses displayed significant negative RCA effects, ranging from-2.037 (DS-NP/R-8-42 x IC-331144) to-0.970 (DML-1112 x DML-1336).

In Environment-2, among the parent varieties, DML-1336 (GCA effect: 0.211) exhibited good general combining ability for the number of kernel rows per ear. In contrast, two parents, DML-1112 (GCA effect:-0.364) and 52212 (GCA effect:-0.228), showed significantly negative GCA effects for this trait.

The hybrid cross 52212 x DML-1336 (SCA effect: 1.038) demonstrated the highest significant positive specific combining ability effect for this trait. This was followed by 52099 x DML-1112 (SCA effect: 0.982), IC-280427 x DS-NP/R-8-42 (SCA effect: 0.833), and DML-1336 x DS-NP/R-8-42 (SCA effect: 0.795). Among the crosses, ten exhibited significantly positive SCA effects, while three displayed significant negative SCA effects, ranging from-0.871 (DML-1336 x DML-1112) to-0.675 (52099 x IC-280427).

Regarding the RCA effects, the cross combination DML-1336 x 52327 (RCA effect: 1.825) had the highest significant positive effect, followed by DS-NP/R-8-42 x DML-1336 (RCA effect: 1.598), IC-280427 x DS-NP/R-8-42 (RCA effect: 1.577), and 52099 x 52327 (RCA effect: 1.25). The cross DS-NP/R-8-42 x 52212 (RCA effect: 0.628) had the lowest significant positive RCA effect for this character. Among the twenty-eight reciprocal crosses, eleven demonstrated highly significant and positive RCA effects, while six crosses displayed significant negative RCA effects, ranging from-1.093 (DML-1112 x IC-331144) to-0.655 (DML-1112 x DML-1336).

In Environment-3, among the parent varieties, 52099 (GCA effect: 0.315) exhibited good general combining ability for the number of kernel rows per ear, whereas parent DML-1336 (GCA effect:-0.393) showed significantly negative GCA effects for this trait.

The hybrid cross IC-280427 x DS-NP/R-8-42 (SCA effect: 2.568) demonstrated the highest significant positive specific combining ability effect for this trait, followed by 52099 x 52212 (SCA effect: 1.997), 52327 x 52212 (SCA effect: 1.122), and 52099 x DML-1336 (SCA effect: 1.050). Among the crosses, thirteen exhibited significantly positive SCA effects, while one cross displayed a significant negative SCA effect of-0.76 (52212 x DML-1336).

For the RCA effects, the cross combination IC-280427 x 52327 (RCA effect: 0.390) had the highest significant positive effect, followed by DML-1112 x IC-331144 (RCA effect: 0.356), IC-331144 x 5237 (RCA effect: 0.236), and DS-NP/R-8-42 x 52327 (RCA effect: 0.201). The cross DML_1336 x 52099 (RCA effect: 0.81) had the lowest significant positive RCA effect for this character. Among the twenty-eight reciprocal crosses, six demonstrated highly significant and positive RCA effects, while six crosses displayed significant negative RCA effects, ranging from-1.614 (DS-NP/R-8-42 x 52099) to-0.705 (52212 x 52099). These findings aligned with the research conducted by Kamble (2012) [10], Bharti *et al*. (2017) [4], Gazala *et al*. (2017) [8], Sandesh *et al*. (2018) [17], Chandel *et al*. (2019) [5], Hassan *et al*. (2020) [1] and Mogesse *et al*. (2015) [22].

B. Number of kernel per row

In environment-1, certain parents displayed notable general combining ability (GCA) effects on the number of kernel rows per ear. Among these parents, 52099 exhibited a strong positive GCA effect (2.055), alongside DS-NP/R-8-42 (1.709) and IC-280427 (0.809) which also showed significant positive effects. Conversely, DML-1336 (-2.796), 52212 (-0.924), DML-1112 (-0.455), and IC-331144 (-0.294) demonstrated significant negative GCA effects on this trait.

Focusing on specific cross combinations, the pairing 52212 x DML-1112 (8.594) showed the most significant positive specific combining ability (SCA) effect for this trait. This was followed by 52212 x IC-280427 (7.370), DML-1336 x DS-NP/R-8-42 (4.328), and 52099 x DML-1336 (4.039). While twelve crosses exhibited significant positive SCA effects, another twelve crosses displayed significant negative effects, ranging from-7.437 (52099 x DS-NP/R-8-42) to-0.702 (IC-280427 x DML-1336).

Investigating reciprocal cross combinations, DS-NP/R-8-42 x DML-1336 (11.277) demonstrated the highest significant positive reciprocal combining ability (RCA) effect. This was followed by 52212 x 52099 (10.892), DS-NP/R-8-42 x 52327 (10.878), and DML-1336 x 52099 (8.370). In contrast, the cross DML-1336 x 52212 (1.042) displayed the lowest positive significant RCA effect. Out of twenty-eight reciprocal crosses, eighteen exhibited highly significant and positive RCA effects, while seven crosses indicated significant negative RCA effects ranging from-10.015 (DS-NP/R-8-42 x IC-331144) to-2.228 (IC-331144 x DML-1336).

Similarly, in environment-2, four parents exhibited positive GCA effects on the number of kernel rows per ear 52099 (2.004), DS-NP/R-8-42 (1.255), 52327 (0.607), and IC-280427 (0.600). Conversely, DML-1336 (-2.390), DML-1112 (-0.806), 52212 (-0.689), and IC-331144 (-0.580) displayed significant negative GCA effects for this trait.

Noteworthy cross combinations included 52212 x DML-1112 (8.430) with the highest significant positive SCA effect, followed by 52212 x IC-280427 (6.514), DML-1336 x DS-NP/R-8-42 (4.837), and 52099 x DML-1336 (4.310). While fourteen crosses had significant positive SCA effects, eleven crosses exhibited significant negative effects ranging from-8.066 (52099 x DS-NP/R-8-42) to-0.602 (52327 x 52212).

The cross combination 52327 x DS-NP/R-8-42 (11.522) displayed the highest significant positive RCA effect, followed by DS-NP/R-8-42 x DML-1336 (11.370), 52212 x 52099 (10.817), and DML-1336 x 52327 (9.085). Conversely, the cross DML-1336 x IC-280427 (0.788) exhibited the lowest positive significant RCA effect. Among the twenty-eight reciprocal crosses, seventeen demonstrated highly significant and positive RCA effects, while seven crosses displayed significant negative effects ranging from-9.983 (DS-NP/R-8-42 x IC-331144) to-2.500 (IC-331144 x DML-1336).

Shifting focus to environment-3, three parents displayed positive GCA effects for the number of kernel rows per ear 52099 (2.139), DS-NP/R-8-42 (1.523), and IC-280427 (0.338). Conversely, four parents, DML-1336 (-2.856), IC-331144 (-0.647), and 52212 (-0.573), exhibited significant negative GCA effects on this trait.

Among cross combinations, 52099 x 52212 (11.270) had the highest significant positive SCA effect, followed by 52327 x DS-NP/R-8-42 (10.925), DML-1336 x DS-NP/R-8-42 (10.215), and 52327 x 52212 (9.235). Out of eighteen crosses, seven exhibited significant negative SCA effects ranging from-11.012 (IC-331144 x DS-NP/R-8-42) to-1.162 (DML-1336 x IC-331144).

The cross DML-1112 x 52212 (8.718) demonstrated the highest significant positive RCA effect, followed by IC-280427 x 52212 (7.765), IC-280427 x 52099 (4.888), and DS-NP/R-8-42 x DML-1336 (4.605). The cross IC-331144 x 52327 (0.789) had the lowest positive significant RCA effect. Among twenty-eight reciprocal crosses, seventeen showed highly significant and positive RCA effects, while seven crosses exhibited significant negative effects ranging from-8.611 (DS-NP/R-8-42 x 52099) to-0.873 (DS-NP/R-8-42 x 52212).

Once again, these findings are consistent with prior studies by Kamble (2012) [10], Bharti *et al*. (2017) [4], Gazala *et al*. (2017) [8], Sandesh *et al*. (2018) [17], Chandel *et al*. (2019) [5], Hassan *et al*. (2020) [1], and Mogesse *et al*. (2015) [22].

C. Number of kernel per ear

In this environment-1, three parent lines, namely 52099 (30.300), DS-NP/R-8-42 (29.315), and IC-280427 (6.148), displayed remarkably positive and significant GCA effects. Conversely, five parent lines, including DML-1336 (-33.363), 52212 (-11.709), 52327 (-10.204), IC-331144 (-6.600), and DML-1112 (-3.118), exhibited notably negative GCA effects on the number of kernels per ear.

Among the various cross combinations, 52212 x DML-1112 (109.310) manifested the highest and positively significant SCA effect for this trait. Additionally, the crosses 52212 x IC-280427 (101.124), DML-1336 x DS-NP/R-8-42 (91.350), and IC-280427 x DS-NP/R-8-42 (57.110) also demonstrated significant positive SCA effects. On the other hand, the cross 52327 x 52099 (11.801) exhibited the lowest positive significant SCA effect. A range of crosses, from 52099 x DS-NP/R-8-42 (-118.748) to 52327 x DML-1112 (-10.81), showcased significant negative SCA effects.

Furthermore, the reciprocal cross of DS-NP/R-8-42 x DML-1336 (202.513) displayed the most pronounced and significant positive RCA effect, followed by DS-NP/R-8-42 x 52327 (171.432), 52212 x 52099 (163.670), and IC-331144 x 52099 (127.327). However, the cross 52099 x 52327 (14.583) revealed the lowest significant positive RCA effect. Notably, several crosses indicated significant negative RCA effects, ranging from-154.605 (DS-NP/R-8-42 x IC-331144) to-6.197 (DML-1112 x 52212).

Within the context of environment-2, the investigation revealed the impact of various parental lines on the kernels per ear trait. Three parent lines, namely 52327 (37.631), 52099 (21.936), and DML-1336 (9.874), exhibited highly significant positive GCA effects. In contrast, four parent lines, DS-NP/R-8-42 (-33.260), IC-331144 (-16.658), IC-280427 (-12.767), and DML-1112 (-7.211), demonstrated notable negative GCA effects.

Regarding SCA effects, the cross 52212 x DS-NP/R-8-42 (158.759) displayed the most substantial and positive impact, followed by DML-1336 x IC-331144 (122.194), 52099 x IC-280427 (105.791), and 52327 x IC-280427 (89.404). Conversely, the cross 52099 x DML-1336 (11.708) had the lowest positive significant SCA effect. Several crosses showed significant negative SCA effects.

Additionally, RCA effects were investigated, with the cross combination IC-331144 x DML-1336 (172.068) demonstrating the highest and significant positive effect, followed by 52212 x 52327 (139.970), IC-331144 x 52327 (109.215), and DML-1336 x 52327 (92.005). Once again, the cross 52099 x 52327 (14.583) displayed the lowest significant positive RCA effect. Some crosses indicated significant negative RCA effects.

In the third environment, the impact of specific parent lines on the kernels per ear trait was assessed. Two parent lines, 52099 (34.215) and DS-NP/R-8-42 (30.006), demonstrated highly significant positive GCA effects. However, five parent lines, including IC-331144 (-12.505), 52212 (-6.318), and 52327 (-5.326), exhibited significantly negative GCA effects.

Among the crosses, the combination DML-1336 x DS-NP/R-8-42 (184.702) displayed the most considerable and positive SCA effect, followed by 52212 x DS-NP/R-8-42 (106.883) and IC-280427 x IC-331144 (22.640). On the contrary, the cross IC-280427 x DML-1112 (13.445) had the lowest positive significant SCA effect. Several crosses showed significant negative SCA effects.

Furthermore, the cross combination DML-1112 x 52212 (145.516) exhibited the highest significant positive RCA effect, followed by DS-NP/R-8-42 x DML-1336 (82.602), DS-NP/R-8-42 x IC-280427 (49.781), and DS-NP/R-8-42 x IC-331144 (44.208). The cross DML-1112 x DML-1336 (18.359) displayed the lowest significant positive RCA effect. Several crosses indicated significant negative RCA effects.

The findings were supported by the research of Amiruzzaman *et al*. (2011), Kamble (2012) [10], Singh *et al*. (2005) [11], Akshata and Mummigatti (2019) [2], Hassan *et al*. (2020) [1], and Onejeme *et al* (2020) [16].

D. 100 kernel weight (g)

In the context of Environment-1, three parental lines displayed robust general combining ability for the 100 Kernel Weight trait: IC-280427 (1.117), 52099 (1.040), and DS-NP/R-8-42 (0.485). Conversely, three parents, namely 52327 (-1.051), IC-331144 (-0.764), and DML-1336 (-0.544), exhibited poor general combining ability.

Among the cross combinations, 52212 x DML-1112 (3.443) demonstrated the most substantial and positively significant Specific Combining Ability (SCA) effect for this trait, closely followed by 52099 x DML-1336 (3.102), 52099 x DML-1112 (2.284), and IC-280427 x DS-NP/R-8-42 (2.049). Conversely, the cross combination IC-331144 x DS-NP/R-8-42 (0.875) displayed the lowest significantly positive SCA effect. Negative SCA effects ranged from-3.209 (DML-1336 x IC-331144) to-0.774 (DS-NP/R-8-42 x DML-1112). Notably, eleven crosses exhibited significant positive SCA effects, while eight crosses displayed negative effects in the context of straight crosses.

In terms of reciprocal crosses, the combination DS-NP/R-8-42 x 52327 (5.092) presented the most prominently positive Reciprocal Combining Ability (RCA) effect, trailed by 52212 x 52099 (4.610), DS-NP/R-8-42 x 52099 (4.132), and DML-1112 x IC-280427 (3.502). Conversely, the combination DML-1336 x IC-280427 (0.987) showcased the lowest positive significant RCA effect. The range of negative RCA effects extended from-3.997 (DML-1112 x IC-331144) to-0.767 (52099 x 52327). Among these reciprocal crosses, twelve demonstrated highly significant and positive RCA effects, while seven crosses displayed significant negative effects.

Similarly, within Environment-2, three parental lines displayed commendable general combining ability for the 100 Kernel Weight trait: IC-280427 (0.663), IC-331144 (0.544), and 52212 (0.419). Conversely, DML-1112 (-1.268) and DML-1336 (-0.521) were identified as subpar general combiners.

The cross combination 52212 x DML-1112 (2.951) showcased the most pronounced and positively significant SCA effect for this trait, trailed by 52099 x DML-1112 (2.299), IC-331144 x DS-NP/R-8-42 (2.231), and 52327 x 52099 (1.974). In contrast, the combination IC-280427 x DS-NP/R-8-42 (0.976) exhibited the lowest significantly positive SCA effect. Negative SCA effects ranged from-1.923 (52327 x DS-NP/R-8-42) to-0.690 (52099 x IC-331144). Straight crosses demonstrated eleven with significantly positive SCA effects and eight with negative effects.

Turning to reciprocal crosses, the combination 52212 x 52327 (4.907) displayed the most prominently positive RCA effect, followed by DML-1336 x 52327 (4.725), DS-NP/R-8-42 x 52327 (4.057), and 52212 x 52099 (3.972). Conversely, the combination DML-1336 x IC-280427 (1.105) had the lowest positive significant RCA effect. The range of negative RCA effects extended from-3.280 (IC-331144 x DML-1336) to-0.753 (IC-280427 x 52099). Among these reciprocal crosses, seventeen showed highly significant and positive RCA effects, while seven displayed significant negative effects.

Finally, in Environment-3, three parental lines exhibited commendable general combining ability for the 100 Kernel Weight trait: 52099 (0.841), 52212 (0.613), and DS-NP/R-8-42 (0.556). Conversely, DML-1336 (-1.283) and IC-280427 (-0.282) demonstrated poor general combining ability.

The cross combination 52099 x 52212 (5.727) displayed the most notable and positively significant SCA effect for this trait, followed by 52327 x DS-NP/R-8-42 (5.700), DML-1336 x DS-NP/R-8-42 (3.777), and 52099 x DML-1336 (3.163). The combination 52212 x DML-1336 (1.392) exhibited the lowest significantly positive SCA effect. Negative SCA effects ranged from-4.91 (IC-280427 x DS-NP/R-8-42) to-0.732 (IC-280427 x DML-1336). Within straight crosses, ten combinations displayed significantly positive SCA effects, while nine exhibited negative effects.

In the context of reciprocal crosses, the combination IC-280427 x 52212 (4.063) showcased the most pronounced positive RCA effect, followed by DML-1336 x 52212 (3.855), DS-NP/R-8-42 x DML-1336 (3.114), and IC-280427 x 52099 (2.742). Conversely, the combination 52212 x DML-1336 (1.392) demonstrated the lowest positive significant RCA effect. Negative RCA effects ranged from-4.853 (DS-NP/R-8-42 x 52099) to-0.858 (DML-1336 x 52327). Among the reciprocal crosses, eleven displayed highly significant and positive RCA effects, while ten exhibited significant negative effects.

These findings resonate with earlier research conducted by Kamble (2012) [10], Aminu *et al*. (2014) [3], Matin *et al*. (2016) [14], Bharti *et al*. (2017) [4], Gazala *et al*. (2017) [8], Sandesh *et al*. (2018) [17], Akshata and Mummigatti (2019) [2], Chandel *et al*. (2019) [5], Hassan *et al*. (2020) [1], and Onejeme *et al*. (2020) [16].

E. Kernel weight per ear (g)

In the context of environment-1, among the eight parent varieties evaluated, three parents demonstrated notable performance as general combiners 52099 (8.404), DS-NP/R-8-42 (5.224), and IC-280427 (3.110). Conversely, four parents exhibited inadequate combiner effects: 52327 (-7.230), DML-1336 (-6.692), 52212 (-1.476), and IC-331144 (-1.422).

Among these, the cross-combination 52212 x DML-1112 (39.931) displayed the most significant and positive Specific Combining Ability (SCA) effects, followed by 52212 x IC-280427 (31.389), DML-1336 x DS-NP/R-8-42 (21.581), and 52099 x DML-1336 (17.718). Conversely, the lowest positive SCA effects for this trait were observed in the cross-combination 52212 x DML-1336 (2.748). The range of SCA effects for kernel weight per ear spanned from-31.595 (52099 x DS-NP/R-8-42) to-2.288 (IC-280427 x DML-1336). Of the twenty-eight straight crosses evaluated, fourteen crosses exhibited highly significant and positive SCA effects, while thirteen crosses displayed noteworthy negative SCA effects for kernel weight per ear.

Among the cross-combinations, DS-NP/R-8-42 x 52327 (52.165) showcased the highest Rank Correlation of Combining Ability (RCA) effects, trailed by 52212 x 52327 (49.615), DS-NP/R-8-42 x DML-1336 (45.657), and IC-331144 x 52099 (33.280). The cross 52099 x 52327 (3.405) exhibited the lowest positive significant SCA effects for this trait. The RCA effects ranged from-40.465 (DML-1112 x IC-331144) to-1.895 (DML-1112 x 52212). Notably, nineteen crosses demonstrated highly significant positive RCA effects, while nine crosses revealed significant negative RCA effects.

Turning to environment-2, within a similar set of eight parents, three parents emerged as favourable general combiners: 52099 (8.2327), DS-NP/R-8-42 (4.175), and IC-280427 (2.209). Meanwhile, four parents exhibited limited combiner potential: DML-1336 (-7.281), 52327 (-4.126), IC-331144 (-2.029), and 52212 (-1.094).

Similar to the previous environment, the cross-combination 52212 x DML-1112 (38.594) presented the highest significant positive SCA effects, followed by 52212 x IC-280427 (30.907), DML-1336 x DS-NP/R-8-42 (20.213), and 52099 x DML-1336 (17.125). The cross-combination 52212 x DML-1336 (1.584) displayed the lowest positive significant SCA effects for this trait. The range of SCA effects for kernel weight per ear varied from-30.828 (52099 x DS-NP/R-8-42) to-1.367 (52327 x DS-NP/R-8-42). Among the twenty-eight straight crosses, fourteen crosses exhibited significantly positive SCA effects, while thirteen crosses exhibited notable negative SCA effects for kernel weight per ear.

Regarding cross-combinations, DS-NP/R-8-42 x 52327 (41.188) showcased the highest RCA effects, followed by 52212 x 52099 (48.522), DS-NP/R-8-42 x DML-1336 (42.207), and 52212 x 52327 (33.632). The cross IC-331144 x IC-280427 (5.500) exhibited the lowest significant positive SCA effects for this trait. RCA effects ranged from-39.668 (DML-1112 x IC-331144) to-2.480 (DML-1112 x 52212). Notably, nineteen crosses demonstrated highly significant positive RCA effects, while nine crosses revealed significant negative RCA effects.

Moving to environment-3, within the group of eight parent varieties, three parents emerged as strong general combiners: 52099 (8.982), DS-NP/R-8-42 (6.216), and IC-280427 (1.086). Conversely, four parents showed limited combiner effects: DML-1336 (-8.511), 52327 (-5.765), IC-331144 (-2.364), and 52212 (-1.020).

In terms of cross-combinations, 52212 x DS-NP/R-8-42 (52.938) exhibited the highest significant positive SCA effects, followed by 52099 x 52212 (52.535), DML-1336 x DS-NP/R-8-42 (45.835), and 52099 x IC-331144 (36.405). The cross combination IC-280427 x DML-1112 (5.267) showed the lowest significant positive SCA effects for this trait. The range of SCA effects for kernel weight per ear extended from-41.23 (IC-331144 x DS-NP/R-8-42) to-1.722 (52212 x DML-1112). Among the twenty-eight straight crosses, eighteen crosses displayed highly significant and positive SCA effects, while eight crosses showed significant negative SCA effects for kernel weight per ear.

In the realm of cross-combinations, DS-NP/R-8-42 x 52212 (41.609) demonstrated the highest RCA effects, trailed by IC-280427 x 52212 (38.285), DS-NP/R-8-42 x DML-1336 (26.697), and IC-280427 x 52099 (18.531). The cross DS-NP/R-8-42 (2.382) displayed the lowest significant positive SCA effects for this trait. RCA effects ranged from-33.506 (DS-NP/R-8-42 x 52099) to-2.242 (DML-1336 x 52212). Notably, thirteen crosses showed highly significant positive RCA effects, while thirteen crosses exhibited significant negative RCA effects. These findings were in line with the research by Katna *et al*. (2005) [11], Rodrigues *et al*. (2005) [20], Kamble (2012) [10], Aminu *et al*. (2014) [3], Sandesh *et al*. (2018) [17], and Hassan *et al*. (2020) [1].

F. Kernel yield per plant (g)

In environment-1 results revealed four parents viz., 52099 (11.727), DS-NP/R-8-42 (4.357), 52212 (1.120) and 52327 (0.658) had highly significant positive GCA effects. Whereas other three parents viz., DML-1336 (-11.349), DML-1336 (-5.449), IC-331144 (-0.844) and IC-280427 (-0.844) displayed significantly negative GCA effects for kernel yield per plant (g).

Significant highest SCA effects for this trait was recorded in the combination 52212 x IC-280427 (44.327) and it was followed by 52212 x DML-1112 (41.563), 52099 x IC-280427 (33.042) and 52327 x 52099 (19.666). The cross 52099 x IC-331144 (2.113) recorded the lowest positive significant SCA effects for this trait. The highly significant and negative SCA effects were expressed by the crosses ranged from-33.831 (52099 x DS-NP/R-8-42) to-1.71 (52212 x IC-331144). Highly significant positive SCA effects were observed for fifteen crosses while, ten crosses recorded significant negative SCA effect for kernel yield per plant. The highest significant RCA effects for this trait was noticed in the combination DS-NP/R-8-42 x 52327 (54.262) and it was followed by 52212 x 52099 (54.035), DS-NP/R-8-42 x DML-1336 (49.435) and 52212 x 52327 (49.075). The highly significant and negative RCA effects were expressed by the crosses which ranged from-51.250 (DML-1112 x DML-1336) to-10.750 (IC-331144 x IC-280427). Eighten crosses expressed highly significant positive RCA effects while, seven recorded significant negative RCA effects.

In environment-2 results revealed three parents viz., 52099 (12.199), DS-NP/R-8-42 (4.089) and DML-1112 (0.873) had highly significant positive GCA effects. Whereas other three parents viz., DML-1336 (-11.840) and IC-331144 (-5.566) displayed significantly negative GCA effects for kernel yield per plant (g).

Significant highest SCA effects for this trait was recorded in the combination 52212 x IC-280427 (42.183) and it was followed by 52099 x IC-280427 (30.942) and DML-1336 x DS-NP/R-8-42 (19.681). The cross 52327 x DML-1336 (1.595) recorded the lowest positive significant SCA effects for this trait. The highly significant and negative SCA effects were expressed by the crosses ranged from-29.526 (IC-280427 x DML-1112) to-1.724 (52212 x DS-NP/R-8-42). Highly significant positive SCA effects were observed for fifteen crosses while, ten crosses recorded significant negative SCA effect for kernel yield per plant.

The highest significant RCA effects for this trait was noticed in the combination 52212 x 52099 (53.390) and it was followed by 52212 x 52099 (52.020), 52212 x 52327 (47.957) and DS-NP/R-8-42 x DML-1336 (46.986). The highly significant and negative RCA effects were expressed by the crosses which ranged from-50.630 (DML-1112 x DML-1336) to-9.767 (IC-331144 x DML-1336). Eighten crosses expressed highly significant positive RCA effects while, seven recorded significant negative RCA effects.

In environment-3 results revealed three parents viz., 52099 (12.824), DS-NP/R-8-42 (6.735) and DML-1112 (2.259) had highly significant positive GCA effects. Whereas other four parents viz., DML-1336 (-13.544), IC-331144 (-6.554), 52327 (-1.178) and IC-280427 (-1.020) displayed significantly negative GCA effects for kernel yield per plant (g).

Significant highest SCA effects for this trait was recorded in the combination 52327 x DS-NP/R-8-42 (58.285) and it was followed by 52099 x 52212 (54.738), DML-1336 x DS-NP/R-8-43 (52.255) and 52327 x 52212 (42.722). The cross IC-280427 x DML-1112 (5.760) recorded the lowest positive significant SCA effects for this trait. The highly significant and negative SCA effects were expressed by the crosses ranged from-52.305 (DML-1336 x DML-1112) to-6.522 (DML-1336 x IC-331144). Highly significant positive SCA effects were observed for eighteen crosses while, seven crosses recorded significant negative SCA effect for kernel yield per plant.

The highest significant RCA effects for this trait was noticed in the combination IC-280427 x 52212 (48.229) and it was followed by DML-1112 x 52212 (46.022), IC-280427 x 52099 (35.852) and DS-NP/R-8-42 x DML-1336 (24.774) The highly significant and negative RCA effects were expressed by the crosses which ranged from-35.686 (DS/NP-R-8-42 x 52099) to-3.817 (IC-331144 x 52212). Fourteen crosses expressed highly significant positive RCA effects while, eleven recorded significant negative RCA effects. Positive significant GCA and SCA effects were reported by earlier researchers Sandesh *et al*. (2018) [17], Akshata and Mummigatti (2019) [2], Chandel *et al*. (2019) [5], Hassan *et al*. (2020) [1], Mogesse *et al*. (2015) [22] and Onejeme *et al*. (2020) [16].

Table 1.a: Analysis of variance of combining ability for different characters in maize under environment I.

Source	DF	Days to 50% tasselling	Days to 50% silking	Days to maturity	Plant height (cm)	Earhead height (cm)	Number of Nodes per plant	Number of Leaves per plant	Number of ears per plant
Mean Sum of Squares									
GCA	7	12.747***	10.194***	15.911***	315.606***	566.927***	0.811***	1.309***	0.052***
SCA	28	10.839***	13.740***	12.113***	366.136***	366.971***	0.988***	1.079***	0.032***
Reciprocal	28	14.113***	14.801***	15.950***	373.975***	347.147***	0.767***	1.306***	0.054***
Error	63	0.701	0.706	1.948	2.977	1.738	0.104	0.12	0.003
σ² GCA		0.753	0.593	0.873	19.539	35.324	0.044	0.074	0.003
σ² SCA		10.137	13.034	10.165	363.159	365.234	0.885	0.959	0.029
σ² RCA		6.706	7.048	7.001	185.499	172.705	0.332	0.593	0.025
σ² A		1.506	1.186	1.745	39.079	70.649	0.088	0.149	0.006
σ² D		10.137	13.034	10.165	363.159	365.234	0.885	0.959	0.029
h²% (N.S.)		0.079	0.054	0.084	0.066	0.116	0.063	0.082	0.097
σ² A/ σ² D		0.149	0.091	0.172	0.108	0.193	0.099	0.155	0.207

Source	DF	Ear length (cm)	Ear girth (cm)	Number of kernel rows per ear	Number pf kernels per row	Number of kernel per ear	100 kernel weight (g)	Kernel weight per ear (g)	Kernel yield per plant (g)
Mean Sum of Squares									
GCA	7	1.676***	4.216***	1.576***	38.348***	7406.233***	10.500***	477.360***	725.580***
SCA	28	4.269***	4.023***	0.664***	32.379***	6939.210***	6.757***	634.873***	998.294***
Reciprocal	28	7.125***	3.859***	1.803***	84.253***	18988.140***	11.692***	1319.426***	2247.734***
Error	63	0.212	0.226	0.194	0.198	19.702	0.263	0.68	1.555
σ² GCA		0.092	0.249	0.086	2.384	461.658	0.64	29.792	45.252
σ² SCA		4.057	3.796	0.47	32.181	6919.509	6.494	634.193	996.739
σ² RCA		3.457	1.816	0.804	42.027	9484.218	5.714	659.373	1123.089
σ² A		0.183	0.499	0.173	4.769	923.316	1.28	59.585	90.503
σ² D		4.057	3.796	0.47	32.181	6919.509	6.494	634.193	996.739
h²% (N.S.)		0.023	0.079	0.105	0.06	0.053	0.093	0.044	0.041
σ² A/ σ² D		0.045	0.131	0.368	0.148	0.133	0.197	0.094	0.091

Table 1.b: Analysis of variance of combining ability for different characters in maize under environment II

Source	DF	Days to 50% tasselling	Days to 50% silking	Days to maturity	Plant height (cm)	Earhead height (cm)	Number of Nodes per plant	Number of Leaves per plant	Number of ears per plant
Mean Sum of Squares									
GCA	7	18.042***	18.679***	13.055***	269.974***	587.463***	0.656***	1.097**	0.023***
SCA	28	11.732***	11.971***	9.289***	332.121***	312.522***	0.859***	0.900***	0.024***
Reciprocal	28	13.650***	12.809***	13.628***	366.550***	339.984***	0.603***	1.090***	0.031***
Error	63	0.724	0.687	1.563	3.298	2.225	0.139	0.280	0.003
σ² GCA		1.082	1.125	0.718	16.667	36.577	0.032	0.051	0.001
σ² SCA		11.008	11.285	7.725	328.822	310.297	0.720	0.620	0.020
σ² RCA		6.463	6.061	6.032	181.626	168.879	0.232	0.405	0.014
σ² A		2.165	2.249	1.436	33.334	73.155	0.065	0.102	0.002
σ² D		11.008	11.285	7.725	328.822	310.297	0.720	0.620	0.020
h²% (N.S.)		0.106	0.111	0.086	0.061	0.132	0.056	0.073	0.062
σ² A/ σ² D		0.197	0.199	0.186	0.101	0.236	0.090	0.165	0.100

Source	DF	Ear length (cm)	Ear girth (cm)	Number of kernel rows per ear	Number pf kernels per row	Number of kernel per ear	100 kernel weight (g)	Kernel weight per ear (g)	Kernel yield per plant (g)
Mean Sum of Squares									
GCA	7	4.833***	3.820***	0.650**	30.828***	8214.086***	6.429***	378.314***	771.464***
SCA	28	4.390***	3.813***	0.931***	35.188***	12416.570***	5.554***	605.041***	946.882***
Reciprocal	28	7.824***	3.291***	1.675***	88.451***	11825.230***	14.726***	1296.132***	2192.917***
Error	63	0.203	0.222	0.192	0.223	25.520	0.251	0.958	1.596
σ² GCA		0.289	0.225	0.029	1.913	511.785	0.386	23.585	48.117
σ² SCA		4.187	3.591	0.739	34.965	12391.050	5.303	604.084	945.286
σ² RCA		3.811	1.535	0.742	44.114	5899.853	7.237	647.587	1095.661
σ² A		0.579	0.450	0.057	3.826	1023.571	0.772	47.170	96.234
σ² D		4.187	3.591	0.739	34.965	12391.050	5.303	604.084	945.286
h²% (N.S.)		0.066	0.078	0.033	0.046	0.053	0.057	0.036	0.045
σ² A/ σ² D		0.138	0.125	0.077	0.109	0.083	0.146	0.078	0.102

Table 1c: Analysis of variance of combining ability for different characters in maize under environment III

Source	DF	Days to 50% tasselling	Days to 50% silking	Days to maturity	Plant height (cm)	Earhead height (cm)	Number of Nodes per plant	Number of Leaves per plant	Number of ears per plant
Mean Sum of Squares									
GCA	7	6.690***	3.901***	5.593***	424.752***	532.870***	0.389**	0.917 *	0.023***
SCA	28	12.841***	14.563***	11.189***	413.652***	385.649***	1.064***	1.141***	0.024***
Reciprocal	28	10.948***	12.103***	11.018***	458.258***	340.917***	0.591***	1.052***	0.031***
Error	63	0.523	0.589	0.977	2.726	2.676	0.125	0.397	0.003
σ² GCA		0.385	0.207	0.288	26.377	33.137	0.016	0.032	0.001
σ² SCA		12.318	13.973	10.212	410.926	382.973	0.938	0.744	0.020
σ² RCA		5.212	5.757	5.020	227.766	169.121	0.233	0.327	0.014
σ² A		0.771	0.414	0.577	52.753	66.274	0.033	0.065	0.002
σ² D		12.318	13.973	10.212	410.926	382.973	0.938	0.744	0.020
h²% (N.S.)		0.041	0.020	0.034	0.076	0.107	0.025	0.042	0.062
σ² A/ σ² D		0.063	0.030	0.057	0.128	0.173	0.035	0.087	0.100

Source	DF	Ear length (cm)	Ear girth (cm)	Number of kernel rows per ear	Number pf kernels per row	Number of kernel per ear	100 kernel weight (g)	Kernel weight per ear (g)	Kernel yield per plant (g)
Mean Sum of Squares									
GCA	7	4.040***	4.661***	0.745**	36.446***	9141.646***	7.279***	536.434***	1014.787***
SCA	28	4.600***	4.065***	1.340***	37.402***	10470.150***	9.408***	740.539***	1093.604***
Reciprocal	28	6.388***	4.178***	2.362***	87.746***	22112.880***	15.497***	1414.114***	2348.688***
Error	63	0.289	0.308	0.242	0.228	28.552	0.227	1.248	1.599
σ² GCA		0.234	0.272	0.031	2.264	569.568	0.441	33.449	63.324
σ² SCA		4.311	3.757	1.097	37.174	10441.600	9.180	739.291	1092.005
σ² RCA		3.049	1.935	1.060	43.759	11042.170	7.635	706.433	1173.545
σ² A		0.469	0.544	0.063	4.527	1139.137	0.881	66.898	126.649
σ² D		4.311	3.757	1.097	37.174	10441.600	9.180	739.291	1092.005
h²% (N.S.)		0.058	0.083	0.026	0.053	0.050	0.049	0.044	0.053
σ² A/ σ² D		0.109	0.145	0.057	0.122	0.109	0.096	0.090	0.116

Table 2.a: General combining ability effects of parents for different characters in maize

Sr. No.	Parents	Number of kernel rows per ear			Number of kernels per row			Number of kernels per ear		
		E-1	E-2	E-3	E-1	E-2	E-3	E-1	E-2	E-3
1	52327	-0.527 **	0.076	0.053	-0.104	0.607 **	0.166	-10.204 **	37.631 **	-5.326 **
2	52099	0.219 *	0.053	0.315 **	2.055 **	2.004 **	2.139	30.030 **	21.936 **	34.215 **
3	52212	-0.217 *	-0.228 *	-0.135	-0.924 **	-0.689 **	-0.573 ***	-11.709 **	0.454	-6.318 **
4	IC-280427	0.264 *	0.148	-0.089	0.809 **	0.600 **	0.338 **	6.148 **	-12.767 **	0.303
5	DML-1336	-0.214 *	0.211 *	-0.393 **	-2.796 **	-2.390 *	-2.856 **	-33.863 **	9.874 **	-41.266 **
6	IC-331144	-0.024	0.151	-0.030	-0.294 **	-0.580 **	-0.647 **	-6.600 **	-16.658 **	-12.505 **
7	DS-NP/R-8-42	0.444 **	-0.048	0.180	1.709 **	1.255 **	1.523 ***	29.316 **	-33.260 **	30.006 **
8	DML-1112	0.054	-0.364 **	0.098	-0.455 **	-0.806 **	-0.090	-3.118 **	-7.211 **	0.891
	SE (gi)±	0.103	0.102	0.115	0.104	0.110	0.112	1.038	1.181	1.250
	CD AT 5%	0.206	0.205	0.230	0.208	0.220	0.223	2.074	2.361	2.497
	CD AT 1%	0.275	0.274	0.307	0.278	0.295	0.298	2.771	3.154	3.336

*,** significant at 5 percent and 1 percent level of significance, respectively

Table 2.b: General combining ability effects of parents for different characters in maize

Sr. No.	Parents	100 kernel weight (g)			Kernel weight per ear (g)			Kernel yield per plant (g)		
		E-1	E-2	E-3	E-1	E-2	E-3	E-1	E-2	E-3
1	52327	-1.051 **	0.107	-0.150	-7.230 **	-4.126 **	-5.765 **	0.658 *	-0.032	-1.178 **
2	52099	1.040 **	0.098	0.841 **	8.404 **	8.237 **	8.982 **	11.727 **	12.199 ***	12.824 **
3	52212	-0.089	0.419 **	0.613 **	-1.476 **	-1.094 **	-1.020 **	1.120 **	0.158	0.479
4	IC-280427	1.117 **	0.663 **	-0.282 *	3.110 **	2.209 **	1.086 **	-0.844 **	0.119	-1.020 **
5	DML-1336	-0.544 **	-0.521 **	-1.283 **	-6.692 **	-7.281 **	-8.511 **	-11.349 **	-11.840 **	-13.544 **
6	IC-331144	-0.764 **	0.544 **	-0.147	-1.422 **	-2.029 **	-2.364 **	-5.449 **	-5.566 **	-6.554 *
7	DS-NP/R-8-42	0.485 **	-0.041	0.556 **	5.224 **	4.175 **	6.216 **	4.357 *	4.089 **	6.735 **
8	DML-1112	-0.196	-1.268 **	-0.149	0.081	-0.01	1.375 **	-0.220	0.873 **	2.259 *
	SE (gi)±	0.120	0.117	0.111	0.193	0.229	0.261	0.292	0.295	0.296
	CD AT 5%	0.240	0.234	0.223	0.385	0.457	0.522	0.583	0.590	0.591
	CD AT 1%	0.320	0.313	0.298	0.515	0.611	0.697	0.779	0.789	0.790

*,** significant at 5 percent and 1 percent level of significance, respectively

Table 3.a: SCA and RCA effects of crosses for different characters in maize

Sr. No.	Crosses		Number of kernel rows per ear			Number of kernels per row			Number of kernels per ear		
			E-1	E-2	E-3	E-1	E-2	E-3	11.801**	88.934**	23.305
1	52327 x 52099	D	0.18	0.667*	-0.563	0.661*	1.552**	1.81**	14.583**	11.427**	7.569
2	52099 x 52327	R	-0.552	1.525**	0.136	1.625**	3.8**	1.2**	-34.162**	-23.726**	108.715
3	52327 x 52212	D	-0.631	-0.234	1.122**	-1.605**	-0.62*	9.235**	97.35**	139.97**	-41.603
4	52212 x 52327	R	0.65	1.577**	-1.198**	7.69**	8.71**	-2.753**	12.229**	89.404**	39.67
5	52327 x IC-280427	D	0.011	0.714*	-0.523	1.18**	1.813**	3.11**	25.452**	40.095**	29.672
6	IC-280427 x 52327	R	-0.592	1.313**	0.39	3.208**	4.577**	1.706**	-13.448**	14.794**	103.008
7	52327 x DML-1336	D	-0.639	0.094	0.425	0.36	0.28	7.37**	91.94**	92.005**	-4.007
8	DML-1336 x 52327	R	0.595	1.825**	-0.303	7.562**	9.085**	0.595	-0.823	35.265**	59.717
9	52327 x IC-331144	D	-0.257	0.474	-0.327	1.143**	1.475**	4.212**	53.702**	109.215**	7.637
10	IC-331144 x 52327	R	-0.142	1.225**	0.236	4.073**	6.1**	0.789*	-5.424	-24.247**	171.62
11	52327 x DS-NP/R-8-42	D	0.258	-0.694*	2.568**	-1.725**	-1.957**	10.925**	171.432**	76.47**	-10.956
12	DS-NP/R-8-42 x 52327	R	1.2	1.297**	0.201	10.878**	11.522**	-1.344**	-10.81**	32.039**	72.977
13	52327 x DML-1112	D	-0.097	-0.391	0.807*	-3.151**	-3.881**	5.535**	94.603**	-23.99**	-43.289
14	DML-1112 x 52327	R	0.895	0.11	0.183	5.412**	5.512**	-3.17**	-34.021**	41.083**	183.212
15	52099 x 52212	D	-0.382	-0.464	1.997**	-3.117**	-2.98**	11.27**	163.67**	-4.19	-35.671
16	52212 x 52099	R	1.615	1.31**	-0.705*	10.892**	10.817**	-3.371**	52.81**	105.791**	-9.603
17	52099 x IC-280427	D	0.334	-0.675*	-0.147	3.981**	4.156**	-0.62	-6.767*	38.172**	86.538
18	IC-280427 x 52099	R	0.438	-0.07	0.828*	0.002	0.462	4.888**	53.488**	11.708**	128.245
19	52099 x DML-1336	D	0.352	0.702*	1.05**	4.039**	4.31**	7.865**	113.63**	90.845**	69.235
20	DML-1336x 52099	R	1.012	-0.48	0.81*	8.37**	6.343**	3.837**	27.243**	-23.398**	132.598
21	52099 x IC-331144	D	-0.026	-0.145	0.552	0.539	0.351	7.93**	127.327**	43.692**	41.886
22	IC-331144 x 52099	R	1.19	0.488	0.844*	7.547**	7.637**	1.504**	-118.748**	-12.281**	61.367
23	52099 x DS-NP/R-8-42	D	-0.318	-0.306	-0.475	-7.437**	-8.066**	4.38**	89.143**	46.717**	-154.585
24	DS-NP/R-8-42 x 52099	R	1.275	1.043**	-1.614**	5.76**	6.03**	-8.611**	48.208**	-27.522**	-94.033
25	52099 x DML-1112	D	0.794	0.982**	-2.075**	3.567**	3.157**	-6.037**	-44.965**	-105.255**	30.555
26	DML-1112 x 52099	R	0.598	-0.04	-0.066	-4.505**	-4.122**	2.27**	101.124**	0.363	2.127
27	52212 x IC-280427	D	0.298	-0.232	0.54	7.37**	6.514**	0.545	4.158	8.512*	131.951
28	IC-280427x 52212	R	0.11	0.058	1.921**	0.422	0.043	7.765**	22.25**	-31.742**	14.575
29	52212 x DML-1336	D	0.418	1.038**	-0.76*	0.645*	1.406**	2.05**	43.567**	26.323**	-2.342
30	DML-1336 x 52212	R	0.613	-0.42	-0.47	1.042**	0.905**	0.634	-17.448**	30.842**	15.77
31	52212 x IC-331144	D	0.513	0.186	-0.128	-2.535**	-1.956**	2.005**	43.973**	54.015**	-43.674
32	IC-331144x 52212	R	1.222	0.537	-0.755*	1.545**	2.487**	-1.675**			

Sr. No.	Crosses		Number of kernel rows per ear			Number of kernels per row			Number of kernels per ear		
			E-1	E-2	E-3	E-1	E-2	E-3	E-1	E-2	E-3
33	52212 x DS-NP/R-8-42	D	-0.627*	-0.771**	1.037**	-1.068**	-1.703**	7.648**	-26.579**	158.759**	106.883**
34	DS-NP/R-8-42 x 52212	R	0.58*	0.628*	0.025	7.065**	7.405**	-0.873*	100.897**	-46.57**	-20.537**
35	52212 x DML-1112	D	0.633*	0.735**	-0.145	8.594**	8.43**	0.01	109.31**	-33.072**	-6.585*
36	DML-1112 x 52212	R	0.045	-0.487	1.395**	-0.568	-0.502	8.718**	-6.197*	36.832**	145.516**
37	IC-280427 x DML-1336	D	-0.2	0.609*	-0.372	-0.702*	-0.016	1.077**	-13.254**	-57.899**	3.875
38	DML-1336 x IC-280427	R	0.5	-0.432	-0.364	2.248**	0.788*	-1.185**	37.32**	30.865**	-33.523**
39	IC-280427 x IC-331144	D	0.135	-0.008	0.157	-2.672**	-2.983**	2.055**	-47.719**	-12.007**	22.64**
40	IC-331144 x IC-280427	R	1.04**	0.24	-1.217**	2.22**	1.925**	-4.431**	32.388**	11.875**	-81.169**
41	IC-280427 x DS-NP/R-8-42	D	1.064**	0.833**	-1.445**	1.787**	1.875**	-8.6**	57.11**	-8.39**	-161.14**
42	DS-NP/R-8-42 x IC-280427	R	-0.407	-0.352	0.125	-6.632**	-6.758**	2.034**	-111.772**	19.875**	49.781**
43	IC-280427 x DML-1112	D	-0.123	-0.021	-0.35	-6.284**	-6.532**	1.508**	-83.384**	1.956	13.445**
44	DML-1112 x IC-280427	R	1.065**	0.732*	-0.887*	4.287**	3.085**	-7.265**	43.96**	-85.955**	-111.56**
45	DML-1336 x IC-331144	D	-0.6*	-0.811**	0.495	-3.959**	-5.144**	-1.162**	-71.521**	122.194**	-7.16*
46	IC-331144 x DML-1336	R	-0.093	-0.465	-0.57	-2.228**	-2.5**	-5.265**	-30.995**	172.068**	-80.03**
47	DML-1336 x DS-NP/R-8-42	D	0.94**	0.795**	1.7**	4.328**	4.837**	10.215**	91.35**	67.429**	184.702**
48	DS-NP/R-8-42 xDML-1336	R	1.775**	1.598**	0.91*	11.277**	11.37**	4.608**	202.513**	-166.855**	82.602**
49	DML-1336x DML-1112	D	0.135	-0.871**	-1.023**	0.689	1.055**	-8.253**	2.689	39.045**	-133.425**
50	DML-1112 x DML-1336	R	-0.97**	-0.655*	0.09	-8.52**	-8.462**	1.394**	-114.022**	-98.82**	18.359**
51	IC-331144 x DS-NP/R-8-42	D	-0.148	0.613*	-1.847**	2.313**	2.485**	-11.012**	35.805**	-37.527**	-189.415**
52	DS-NP/R-8-42 x IC-331144	R	-2.037**	-0.83**	0.129	-10.015**	-9.983**	1.467**	-154.605**	-8.067*	44.208**
53	IC-331144 x DML-1112	D	0.164	0.381	-0.977**	0.52	1.135**	-9.89**	27.254**	-1.098	-162.045**
54	DML-1112 x IC-331144	R	-1.07**	-1.093**	0.356	-10.002**	-9.563**	1.673**	-138.895**	-92.95**	39.738**
55	DS-NP/R-8-42 x DML-1112	D	-0.796**	-0.202	-0.91**	-2.839**	-2.524**	-7.672**	-53.452**	-62.678**	-116.962**
56	DML-1112 x DS-NP/R-8-42	R	-0.283	-0.16	-0.526	-7.458**	-7.427**	-2.105**	-103.88**	22.503**	-34.905**
	S.E.(Sij)±		0.275	0.274	0.308	0.278	0.295	0.298	2.774	3.157	3.340
	CD 95%		0.551	0.547	0.615	0.556	0.589	0.596	5.544	6.309	6.674
	CD 99%		0.736	0.731	0.822	0.743	0.787	0.797	7.407	8.430	8.917
	S.E.(Rij)±		0.312	0.310	0.348	0.315	0.334	0.338	3.139	3.572	3.778
	CD 95%		0.623	0.619	0.696	0.629	0.667	0.675	6.272	7.138	7.550
	CD 99%		0.832	0.827	0.930	0.840	0.891	0.901	8.380	9.537	10.088

*,** significant at 5 percent and 1 percent level of significance, respectively
D-Direct cross, R-Reciprocal cross

Table 3.b: SCA and RCA effects of crosses for different characters in maize

Sr. No.	Crosses		100 kernel weight (g)			Kernel weight per ear (g)			Kernel yield per plant (g)		
			E-1	E-2	E-3	E-1	E-2	E-3	E-1	E-2	E-3
1	52327 x 52099	D	0.429	1.974**	-1.595**	5.042**	6.481**	0.55	19.666**	19.666**	6.77**
2	52099 x 52327	R	-0.767*	2.977**	0.428	3.405**	8.388**	3.605**	15.68**	11.613**	17.319**
3	52327 x 52212	D	-1.484**	-0.587	1.97**	-13.249**	-10.563**	26.993**	-12.252**	-11.723**	42.722**
4	52212 x 52327	R	1.845**	4.907**	-2.894**	29.295**	33.632**	-13.886**	49.075**	47.957**	-15.878**
5	52327 x IC-280427	D	-0.143	1.716**	-0.45	5.465**	7.842**	2.577**	11.366**	8.721**	19.78**
6	IC-280427 x 52327	R	-0.708	2.4**	0.621*	3.92**	7.62**	7.377**	26.12**	24.978**	8.699**
7	52327 x DML-1336	D	-1.255**	0.39	1.83**	-7.645**	-5.601**	23.397**	1.451	1.595*	42.11**
8	DML-1336 x 52327	R	2.05**	4.725**	-0.858*	24.752**	27.368**	-5.705**	46.16**	44.818**	0.887
9	52327 x IC-331144	D	1.048**	1.516**	-0.54	0.133	3.317**	10.05**	4.092**	5.309**	22.438**
10	IC-331144 x 52327	R	0.082	3.195**	0.371	9.845**	14.602**	0.79	27.45**	27.93**	2.21*
11	52327 x DS-NP/R-8-42	D	-0.221	-1.923**	5.7**	1.852**	-1.367*	52.938**	-11.987**	-12.902**	58.285**
12	DS-NP/R-8-42 x 52327	R	5.092**	4.057**	-0.467	52.165**	49.188**	2.382**	54.262**	53.39**	-9.582**
13	52327 x DML-1112	D	0.325	-1.14**	2.05**	-4.517**	-6.211**	17.225**	-8.975**	-8.17**	32.265**
14	DML-1112 x 52327	R	1.932**	1.558**	0.918**	15.513**	15.007**	-5.304**	29.013**	30.82**	-6.131**
15	52099 x 52212	D	-2.41**	-1.903**	5.727**	-10.682**	-10.787**	52.535**	-20.546**	-21.468**	54.738**
16	52212 x 52099	R	4.61**	3.972**	-1.888**	49.61**	48.522**	-9.87**	54.035**	52.02**	-19.73**
17	52099 x IC-280427	D	0.584	0.533	-0.172	13.412**	14.071**	-6.002**	33.042**	30.942**	-1.46
18	IC-280427 x 52099	R	-0.38	-0.753*	2.742**	-6.735**	-6.298**	18.531**	0.025	-0.805	35.852**
19	52099 x DML-1336	D	3.102**	1.104**	3.163**	17.718**	17.125**	35.792**	11.55**	9.813**	41.777**
20	DML-1336x 52099	R	0.587	2.515**	1.928**	29.18**	32.838**	14.689**	36.082**	34.243**	9.243**
21	52099 x IC-331144	D	0.417	-0.69*	2.885**	7.589**	6.876**	36.405**	2.113*	1.337	37.76**
22	IC-331144 x 52099	R	2.528**	2**	1.76**	33.28**	31.765**	11.484**	36.56**	36.305**	5.16**
23	52099 x DS-NP/R-8-42	D	-1.412**	-1.184**	0.005	-31.595**	-30.828**	17.715**	-33.831**	-28.238**	33.332**
24	DS-NP/R-8-42 x 52099	R	4.132**	3.127**	-4.853**	23.933**	23.005**	-33.506**	31.257**	37.275**	-35.686**
25	52099 x DML-1112	D	2.284**	2.299**	-3.805**	17.094**	15.761**	-25.385**	17.484**	19.281**	-15.927**
26	DML-1112 x 52099	R	-0.023	-0.157	0.716*	-18.573**	-20.942**	14.005**	-14.475**	-10.132**	17.244**
27	52212 x IC-280427	D	1.775**	1.185**	0.105	31.389**	30.907**	5.575**	44.327**	42.183**	-0.417
28	IC-280427x 52212	R	-0.363	0.29	4.063**	5.273**	5.658**	38.285**	0.813	-1	48.229**
29	52212 x DML-1336	D	0.956**	1.934**	1.392**	2.748**	1.584*	9.005**	6.925**	7.204**	21.11**
30	DML-1336 x 52212	R	-1.207**	2.985**	-1.323**	9.625**	8.55**	-2.242**	20.8**	20.768**	1.275
31	52212 x IC-331144	D	-0.224	0.344	-0.893**	-4.101**	-6.534**	7.052**	-1.71*	-1.724*	18.268**
32	IC-331144x 52212	R	0.272	2.95**	-0.994**	12.95**	9.76**	-8.047**	22.67**	21.952**	-3.817**

Sr. No.	Crosses		100 kernel weight (g)			Kernel weight per ear (g)			Kernel yield per plant (g)		
			E-1	E-2	E-3	E-1	E-2	E-3	E-1	E-2	E-3
33	52212 x DS-NP/R-8-42	D	-0.6	-1.129**	2.333**	-2.827**	0.018	27.298**	-0.817	-1.462	39.793**
34	DS-NP/R-8-42 x 52212	R	1.68**	1.897**	0.838*	24.16**	24.615**	-0.477	38.9**	39.645**	0.204
35	52212 x DML-1112	D	3.443**	2.951**	-0.32	39.931**	38.594**	-1.722*	41.563**	42.357**	1.35
36	DML-1112 x 52212	R	0.033	-0.155	3.855**	-1.895**	-2.48**	41.609**	-1.472	0.928	46.022**
37	IC-280427 x DML-1336	D	1.71**	-0.056	-0.732*	-2.288**	-3.921**	6.215**	-9.265**	-7.376**	6.833**
38	DML-1336 x IC-280427	R	0.987**	1.105**	-1.449**	8.71**	7.167**	-6.208**	2.488**	7.353**	-11.573**
39	IC-280427 x IC-331144	D	-1.408**	0.305	0.192	-10.917**	-13.581**	6.058**	-17.364**	-14.825**	6.47**
40	IC-331144 x IC-280427	R	2.55**	-1.355**	-2.755**	7.96**	5.5**	-17.668**	2.643**	6.778**	-19.236**
41	IC-280427 x DS-NP/R-8-42	D	2.049**	0.976**	-4.91**	15.032**	15.078**	-33.672**	13.307**	15.16**	-44.262**
42	DS-NP/R-8-42 x IC-280427	R	-1.425**	-1.512**	0.45	-29.195**	-30.277**	12.871**	-40.805**	-36.393**	14.193**
43	IC-280427 x DML-1112	D	-1.243**	-1.376**	-1.495**	-20.503**	-21.763**	5.267**	-31.891**	-29.526**	5.76**
44	DML-1112 x IC-280427	R	3.502**	2.927**	-2.45**	10.487**	6.87**	-24.388**	5.94**	11.505**	-32.854**
45	DML-1336 x IC-331144	D	-3.209**	-1.596**	-0.443	-18.318**	-17.474**	-5.142**	-20.806**	-20.981**	-6.522**
46	IC-331144 x DML-1336	R	-0.387	-3.28**	-1.738**	-9.532**	-7.647**	-18.49**	-10.75**	-9.767**	-21.669**
47	DML-1336 x DS-NP/R-8-42	D	0.932**	1.418**	3.777**	21.581**	20.213**	45.835**	19.432**	19.681**	52.255**
48	DS-NP/R-8-42 xDML-1336	R	3.467**	3.685**	3.114**	45.657**	42.207**	26.697**	49.435**	46.98**	24.774**
49	DML-1336x DML-1112	D	-0.395	-0.437	-3.405**	-10.221**	-9.411**	-31.068**	3.135**	2.468**	-52.305**
50	DML-1112 x DML-1336	R	-3.175**	-2.567**	0.391	-30.267**	-28.677**	-8.3**	-51.25**	-50.63**	4.295**
51	IC-331144 x DS-NP/R-8-42	D	0.875**	2.231**	-4.722**	15.977**	15.113**	-41.23**	16.662**	15.075**	-50.66**
52	DS-NP/R-8-42 x IC-331144	R	-3.59**	-0.408	0.598	-37.763**	-37.45**	13.379**	-42.46**	-42.768**	14.294**
53	IC-331144 x DML-1112	D	0.938**	-0.089	-3.95**	7.382**	9.376**	-39.742**	4.605**	4.792**	-46.785**
54	DML-1112 x IC-331144	R	-3.997**	-2.97**	0.805*	-40.465**	-39.668**	13.658**	-45.29**	-46.313**	5.775**
55	DS-NP/R-8-42 x DML-1112	D	-0.774*	0.333	-2.278**	-12.011**	-11.217**	-20.86**	-0.477	-2.591**	-40.748**
56	DML-1112 x DS-NP/R-8-42	R	-1.65**	-2.098**	-0.256	-20.003**	-18.272**	-12.21**	-38.735**	-38.475**	-4.527**
	S.E.(Sij)±		0.321	0.313	0.298	0.516	0.612	0.698	0.779	0.789	0.790
	CD 95%		0.641	0.626	0.595	1.030	1.222	1.395	1.558	1.578	1.579
	CD 99%		0.856	0.836	0.795	1.376	1.633	1.864	2.081	2.108	2.110
	S.E.(Rij)±		0.363	0.354	0.337	0.583	0.692	0.790	0.882	0.893	0.894
	CD 95%		0.725	0.708	0.673	1.166	1.383	1.578	1.762	1.785	1.787
	CD 99%		0.969	0.946	0.900	1.557	1.848	2.109			

*,** significant at 5 percent and 1 percent level of significance, respectively
D-Direct cross, R-Reciprocal cross

Conclusions

The three parental lines *viz.* 52099, DS-NP/R-8-42 and IC-280427 were identified as good general combiners for kernel yield and other important characters. These potential lines should be exploited for the development of synthetic maize varieties. On the basis of *per se* performance, significant heterosis and SCA effects of crosses, four straight crosses *viz.*, DML-1336 x DS-NP/R-8-42, 52099 x DML-1336, 52327 x 52099 and 52212 x DML-1112 were promising. On the basis of *per se* performance, significant heterosis and RCA effects of reciprocal crosses, four crosses *viz.*, DS-NP/R-8-42 x DML-1336, IC-331144 x 52099, DML-1336 x 52099 and 52212 x 52099 were promising. The estimates of components of SCA variance were higher than the components of GCA variance which indicated preponderance of non-additive gene action for all sixteen characters studied under present investigation.

Future Scope

That may be utilized in crossing programme in order to generate wide genetic variability for effective selection in developing high yielding and early maturing hybrids as well as synthetic varieties.

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