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Combining ability analysis in sweet sorghum (*Sorghum bicolor* L. Moench)

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Abstract
The experiment was undertaken on Line x Tester analysis for ancillary data cane, juice yield and its component traits in crosses of A and R lines of sweet sorghum at All India Co-ordinated Sorghum Improvement Project, M.P.K.V., Rahuri, during the year 2017-18 with objectives to study the general and specific combining ability of parents and hybrids. The CMS lines (females), ten testers (males) and their thirty F_1's hybrid was studied by using L x T design. Observations were recorded on fourteen characters viz., Days to 50% flowering, Days to physiological maturity, Internode / Plant, Plant height (cm), Stem girth (cm), Total biomass yield (t/ha), Cane weight (t/ha), Cane harvest index (%), Juice yield (lit/ha), Brix (%), Reducing sugar (%), Non-reducing sugar (%), Total sugar (%), Computed ethanol yield (lit/ha). Based on result obtained the hybrids CMS-1409A x RSSV-503, ICMS-479A x RSSV-509, ICMS-479A x RSSV-313, ICMS-479A x RSSV-260, CMS-1409A x RSSV-542 were most promising and could be exploited for further hybrid development. While the cms viz., CMS-1409, CMS-185A and restorer lines RSSV-260, RSSV-512, RSSV-509 and RSSV-498 were observed as good general combiners and need due consideration for future hybridization programme.

Keywords: GCA, SCA, L x T, sweet sorghum

Introduction
Sorghum is recognized as one of the best crops for biomass energy feedstock. The sugar and starch in sweet sorghum could be fermented to ethanol and liquid cellulose could be gasified to methane. The concept of high energy sorghum is now gaining forward. The recent national bio-fuel policy of government of India state that an indicated target of 20% percent ethanol blending with petrol viewed largely a measure of environmental sustainability and reduced the dependence on fossil fuels. The traditional route of producing ethanol as product of sugar industry will not meet this huge demand. Therefore, as demand for production of fuel ethanol, through renewable sources increase to unprecedented levels, feed stock for ethanol production will become more diverse. High biomass sweet sorghum would be a best option owing to its wider adoption. Therefore, sweet sorghum being a water use efficient non-invasive crop having under adaptability will meet the requirement of upcoming ethanol firms that has not only significant impact on sustaining the environment but also on livelihood opportunities at small farmer in semi-arid tropics.
Combining ability analysis provides the information for selection of the desirable parents and cross combinations for exploitation. The choice of parents in any breeding programme has to be based on complete genetic information and knowledge of combining ability of parents and not merely on field performance.

Materials and methods
The experimental material for the present study comprised of three male sterile line, ten restorers, their resulting 30 hybrids and one hybrid check phule vasundhara. During *rabi* 2017-18 three male sterile lines and ten restores were sown at Sorghum Improvement Project, M.P.K.V., Rahuri and these lines and testers were crossed in Line x Tester design to produce 30 possible hybrids. The experiment was conducted during *kharif* 2018 by using 13 parents, their 30 hybrids along with one standard check phule vasundhara at Sorghum Improvement Project, M.P.K.V., Rahuri. The observations were recorded on eight characters viz., Days to physiological maturity, Internode / Plant, Plant height (cm), Stem girth (cm), Total biomass yield (t/ha), Cane weight (t/ha), Cane harvest index (%), Juice yield (lit/ha), Brix (%), Reducing sugar (%), Non-reducing sugar (%), Total sugar (%), Ethanol yield (lit/ha). The data was subjected to the analysis of combining ability as per Kempthorne (1957) [8] and modified by Arunachalam (1974) [2].

Results and Discussion

Analysis of Variance for Combining Ability

The analysis of variance for combining ability is presented in Table 1. The ANOVA indicated that the genotypes were differing significantly for all the traits studied indicating the presence of genetic variability in the material used in the present study. The mean square due to lines, testers as well as lines vs. testers interaction were found significant for almost all the traits, except the magnitude of variance in lines and testers was found non-significant for internode per plant, in lines it is non-significant for total sugar and also for magnitude of variance in lines and lines vs. testers found non-significant for brix. The estimates of GCA and SCA variance found significant for all the characters under studies, however the estimates of GCA variance found non-significant for brix per cent and reducing sugar percent.

Sprague and Tatum (1942) [12] introduced the concept of general combining ability (GCA) and specific combining ability (SCA) to distinguish between the average performance of parents in crosses and the deviation of individual crosses from its average. The analysis of combining ability partition of the total genetic variance into variance due to general combining ability representing additive type of gene action and variance due to specific combining ability regards as a measure of non-additive gene action.

General combining ability

Genotypes which flower early with negative GCA values are preferred, because it matures early and escape from abiotic or biotic stresses. The female parent CMS-1409A (-1.96) showed significant GCA effects in the desirable direction. The male parents viz., RSSV-498 (-2.43), RSSV-542 (-2.32), RSSV-512 (-1.10), and RSSV-417 (-0.98) displayed significant gca effects in the desirable direction. Days to physiological maturity, significant negative GCA effects were recorded by female parent CMS-1409A (-1.82) while, CMS-185A displayed significant positive GCA effect (1.68). Among male parents RSSV-542 (-2.74) and RSSV-498 (-2.52) displayed significant GCA effects in the desirable direction. CMS-1409A recorded average gca effect (0.278) for internodes per plant. Male parent RSSV-260 (1.93) recorded highest significant positive GCA effect followed by RSSV-509. Genotypes which are taller and having positive values of GCA are preferred for plant height. Significant positive GCA effect was recorded by female parent CMS-185A (7.758), and CMS-1409 A (4.78). As regards to male parents, RSSV-260 (34.69) recorded highest significant positive GCA effect followed by RSSV-509 (26.80), RSSV-512 (15.02) and RSSV-386 (4.24). The significant positive GCA effect was estimated by the female parent CMS- 1409A (0.316) while, Male parent, RSSV-260 (2.24) recorded highest significant positive GCA effect followed by RSSV-509 (0.75) for stem girth. Among the lines tested, for total biomass yield CMS-185A (2.32) recorded significant positive GCA effects while, among the male parents, RSSV-260 (10.03) recorded highest significant positive GCA effects followed by RSSV-512 (3.92), RSSV-509 (1.431) and RSSV-386 (1.33). For cane weight, significant positive GCA effect was recorded by female parent CMS-185A (2.23), male parents, RSSV-260 (10.03) recorded highest significant positive GCA effect followed by RSSV-512 (3.92) and RSSV-509 (1.43). Among the lines tested for cane harvest index CMS-185A (1.15**) recorded significant positive GCA effects, the male parents, RSSV-260 (4.067) recorded highest significant positive GCA effects followed by RSSV-512 (1.76), RSSV-386 (0.712) and RSSV-509 (0.52). The significant positive GCA effect for juice yield was recorded by female parents CMS-1409A (752.91) and CMS-185A (199.2), male parents RSSV-260 (4240.9) recorded highest significant positive GCA effect followed by RSSV-509 (2289.14) and RSSV-512 (2122.81). Genotypes which are having high level of brix percentage and positive GCA values are preferred. For brix, significant positive GCA effect was recorded by female parent CMS-1409A (0.606), As regards to male parents, RSSV-509 (1.29) recorded highest significant positive GCA effect followed by RSSV-498 (0.52) and RSSV-313 (0.406). In sweet sorghum negative value or lower value for reducing sugar is preferred. Significant negative GCA effect was recorded by female parent ICMS-479 (-0.096), Among the male parents, RSSV-498 (-0.386) recorded highest significant negative GCA effects followed by RSSV-503 (-0.263. Total sugar and non-reducing sugar, significant positive GCA effects were recorded by female parents CMS-1409 (0.86) (0.77) and CMS-185 (0.012) (0.011), Among the male parents, RSSV-260 (0.76) (0.47) recorded highest significant positive GCA effects followed by RSSV-509 (0.72) (0.85) and RSSV-417 (0.72) (0.398). The significant positive GCA effect was recorded by female parent CMS-1409A (86.75) and CMS-185A (11.89), Male parent RSSV-260 (301.9) recorded highest significant positive GCA effect followed by RSSV-509 (171) and RSSV-512 (142.9), were found best general combiners for ethanol yield. Female parent line ICMS-479A displayed significant negative GCA effect for plant height, stem girth, total biomass yield, cane weight, cane harvest index, juice yield, total sugar, non-reducing sugar and ethanol yield, while, female line CMS 185-A showed significant negative GCA effect for brix percentage. Male parent RSSV-620 (-0.079) recorded highest significant negative GCA effect for cane harvest index. Male parent RSSV-417 (0.326) recorded highest significant positive GCA effect for reducing sugar percentage. Male parent RSSV-313 (-0.79) (-0.94) recorded highest significant negative GCA effect for total sugar and non-reducing sugar content respectively. The results in the present investigation are in accordance with the findings reported by various workers Kulkarni *et al*. (1991) [9], Ganesh *et al*. (1995), Kumar and Kumar (1998) [10], Chaudhari and Narkhede (2004) [4], Agrawal *et al*. (2005) [1], Indubala (2010) [6], Umakantha *et al*. (2012) [14], Bahadure *et al*. (2015) [3], Kumar *et al*. (2017) [11], Soujanya *et al*. (2018) [13] and Ingle *et al*. (2018) [7].

Specific combining ability

The results on specific combining ability of different hybrids for fourteen characters study have been discussed as under (Table 3).

Days to 50% flowering

For days to 50 percent flowering, ten cross combinations exhibited significant negative SCA effects, it indicates earliness. The cross-combination CMS-185A x RSSV-260 (-4.078) showed highest magnitude of significant negative SCA effect followed by ICMS-479A x RSSV-503 (-3.44) and ICMS-479 x RSSV-498 (-2.67).

Days to maturity

The cross-combination CMS-185A x RSSV-260 (-4.12) exhibited highest magnitude of significant negative SCA effect followed by ICMS-479A x RSSV-512 (-3.03) and ICMS-479A x RSSV-503(-2.59).

Internodes/plant

For the trait of nodes/plant only one of the hybrids ICMS 479A x RSSV-260 (1.20) exhibited the significant positive SCA effect at 5% level of significance in desirable direction.

Stem Girth (cm)

The cross combination, CMS-185A x RSSV-386 (1.27) exhibited highest magnitude of significant positive SCA effect followed by ICMS-479A x RSSV-542 (1.25) and CMS-1409A x RSSV-503 (1.24).

Plant Height (cm)

Among thirty hybrids under study, significant positive and negative SCA effects were recorded by 12 and 13 cross combinations, respectively for plant height. The hybrids CMS-185A x RSSV-498 (28.97), CMS-185A x RSSV-313 (20.08) and ICMS-479A x RSSV-417 (19.13) recorded higher magnitude of significant positive SCA effects for plant height.

Total Biomass Yield (t/ha)

The maximum positive sca effect was marked by CMS-1409A x RSSV-503 (8.32) followed by ICMS-479 x RSSV-509 (7.66) and ICMS-479A x RSSV-260 (4.90). The highest significant negative SCA effect was recorded CMS-1409A x RSSV-509 (-10.16).

Cane Weight (t/ha)

The highest magnitude of significant positive SCA effect was marked in cross CMS-1409A x RSSV-503 (8.35) followed by ICMS-479A x RSSV-509 (7.674) and ICMS-479 x RSSV-260 (4.92).

Cane Harvest Index (%)

The highest magnitude of significant positive SCA effect was marked in cross CMS-1409A x RSSV-503 (3.881) followed by ICMS-479A x RSSV-509 (3.578) and ICMS-479 x RSSV-260 (2.00).

Juice Yield (lit/ha)

The hybrids CMS-1409A x RSSV-503 (3221), ICMS-479A x RSSV-509 (1965) and ICMS-479A x RSSV-313 (1857) recorded higher magnitude of significant positive SCA effects.

Brix (%)

For brix percentage, nine cross combinations were exhibited significant positive SCA effects. The cross-combination CMS-185A x RSS-453 (1.84) showed highest magnitude of significant positive SCA effect followed by ICMS-479A x RSSV- 260 (1.76) and CMS-185A x RSSV-313 (1.51).

Reducing sugar (%)

Among thrity hybrids under study eleven cross combnations shows significant negative SCA effects for reducing sugar which is desirable. The cross combination ICMS-479A x RSSV-386 showed highest negative SCA effect.

Total Sugar (%)

For total sugar percentage, 11 cross combination were exhibited positive SCA effects. The cross combination ICMS-479A x RSSV-453 (1.44), showed highest magnitude of significant positive SCA effects for total sugar followed by CMS-1409A x RSSV-386 (1.09) and ICMS-479A x RSSV-260 (0.97).

Non-reducing Sugar (%)

For non-reducing sugar percentage, 11 cross combinations were exhibited significant positive SCA effects. The cross-combination CMS-1409A x RSSV-542 (1.326), showed highest magnitude of significant positive SCA effect for total sugar and non-reducing sugar respectively, followed by ICMS-479A x RSSV-453 (1.438), ICMS-479A x RSSV-509 (0.77).

Ethanol Yield (lit/ha)

As regards to ethanol yield per hectare, 14 hybrids showed significant positive SCA effects. The highest positive SCA effect was exhibited by CMS-1409 x RSSV-503 (192.69), ICMS-479A x RSSV-509 (158.31) followed by ICMS-479A x RSSV-260 (144.22). The highest significant negative SCA effect was recorded CMS-1409 x RSSV-509 (-201.08).

In the present investigation, three types of parental combinations were observed in the crosses. However, majority of the crosses exhibited high SCA effects as a result of either high x low or low x high or high x high GCA parents indicating a genetic interaction of the additive x dominance or dominance x additive or dominance x dominance interactions. These findings are in agreement with earlier reports of Chaudhari and Narkhede (2004) [4], Agrawal *et al*. (2005) [1] and Soujanya *et al*. (2018) [13].

In general, the parents RSSV-260, RSSV-512, RSSV-509, RSSV-503 and RSSV-386 observed good general combiners for juice yield and its contributing traits. Among the lines, CMS 1409 has been observed as best general combiner for juice yield and most of the juice yield contributing traits. Therefore, these parental lines can be utilized in hybridization programme for the improvement of sweet sorghum for juice yield. The hybrid combinations, CMS-1409 x RSSV-260, ICMS-479A x RSSV- 260 and CMS-185A x RSV-260 exhibited high SCA effects for juice yield and most of its contributing traits. These hybrids can be exploited for cultivation of commercial hybrids of sweet sorghum.

Table 1: Analysis of variance for combining ability and estimates of gca and sca variances in sweet sorghum

Sources	DF	Days to 50% flowering	Days to maturity	Internodes/ Plant	Plant height (cm)	Stem girth (cm)	Total biomass yield (t/ha)	Cane weight (t/ha)
Replication	2	0.49	0.70	2.077	20.98	0.008	0.84	0.69
Treatments	42	116.59**	112.25**	6.84**	6944.82**	5.53**	217.95**	217.83**
Parents	12	312.17**	300.17**	9.47**	15115.92**	0.77**	172.72**	171.32**
Line	2	3.11*	2.78**	0.44	1013.78**	0.19**	39.54**	38.29**
Testers	9	342.00**	326.90**	1.55	804.45**	0.98**	34.78**	34.79**
Line vs. Tester	1	661.88**	654.38**	98.80**	172123.48**	0.005	1680.48**	1666.13**
Parent vs. hybrid	1	145.22**	156.84**	36.66**	46282.02**	57.97**	3722.59**	3722.98**
Hybrids	29	34.67**	32.96**	4.73**	2207.21**	5.70**	115.81**	116.21**
Error	84	0.814	2.62	1.04	20.59	0.01	0.40	0.45

Estimates							
σ^2_{gca}		3.7679**	3.3884**	0.2709**	187.4018**	0.3357**	8.9385**	8.9780**
σ^2_{sca}		6.5094**	5.9005**	0.3168*	406.3949**	1.2207**	25.5500**	25.6523**
σ^2_A		7.5358	6.7767	0.5417	374.8036	0.6715	17.8769	17.9561
σ^2_D		6.5094	5.9005	0.3168	406.3949	1.2207	25.5500	25.6523
σ^2_A/var $_D$		1.1577	1.1485	1.7098	0.9223	0.5501	0.6997	0.7000

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance.

Sources	DF	Cane harvest index (%)	Juice yield (lit/ha)	Brix (%)	Reducing Sugar (%)	Total sugar (%)	Non-reducing sugar (%)	Ethanol yield (lit/ha)
Replication	2	0.02977	137105.68	0.389	0.040*	0.12	0.120	1057.49
Treatments	42	71.09173**	17549920.11**	4.74**	0.49**	7.52**	6.22**	106579.82**
Parents	12	93.59920**	5504988.15**	2.07**	0.49**	10.29**	8.21**	36768.10**
Line	2	10.13121**	1049284.11**	0.33	0.16**	0.093	0.47**	734.33
Testers	9	35.30820**	4316098.87**	2.68**	0.24**	4.21**	4.66**	7183.78**
Line vs. Tester	1	961.39310**	25116399.80**	0.12	3.33**	85.45**	55.61**	375094.53**
Parent vs. hybrid	1	1192.82877	60148528.57**	18.53**	0.94**	59.21**	46.33**	689550.74**
Hybrids	29	23.09770	21065112.36**	5.37**	0.47**	4.59**	4.009**	115364.98**
Error	84	0.16487**	75487.78	0.36	0.011	0.067	0.080	354.09
Estimates								
σ^2_{gca}		1.8485 **	1672608.63**	0.3464	0.0193	0.6783**	0.5749**	12119.0461**
σ^2_{sca}		5.5310 **	3339231.72**	1.6275**	0.1573**	0.9199**	0.7253**	16776.0130**
σ^2_A		3.6971	3345217.2663	0.6927	0.0387	1.3567	1.1497	24238.0923

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance.

Table 2: General combining ability effects of parents for cane, juice yield and its contributing traits in sweet sorghum

Sr. No.	Name of parents	Days to 50% Flowering	Days to maturity	Nodes/ plant	Plant height (cm)	Stem girth (cm)	Total biomass yield (t/ha)	Cane weight (t/ha)
	Female	1	2	3	4	5	6	7
1	CMS-185A	1.63**	1.678**	-0.189	7.578**	-0.034	2.321**	2.338**
2	ICMS-479A	0.33*	0.144	-0.089	-12.356**	-0.282**	-2.404**	-2.407**
3	CMS-1409A	-1.967**	-1.822**	0.278	4.778**	0.316**	0.083	0.068
	SE ±	0.1647	0.2954	0.1867	0.8286	0.0185	0.1169	0.1228
	Male							
4	RSSV-542	-2.322**	-2.744**	-0.956**	-14.311**	-1.401**	-0.592**	-0.588*
5	RSSV-260	5.678**	5.256**	1.933**	34.689**	2.236**	10.033**	10.037**
6	RSSV-509	-0.433	-0.856	1.044**	26.80**	0.758**	1.431**	1.435**
7	RSSV-386	1.122**	0.367	0.378	4.244*	-0.103**	1.329**	1.333**
8	RSSV-498	-2.433**	-2.522**	0.267	-13.311**	-0.521**	-5.155**	-5.151**
9	RSSV-417	-0.989**	-0.744	-0.733*	-25.20**	-1.079**	-4.245**	-4.254**
10	RSSV-453	-0.656*	-0.411	-1.178**	-25.422**	-0.200**	-2.085**	-2.094**
11	RSSV-313	1.122**	1.367*	-1.511**	-4.756**	-0.843**	-3.297**	-3.306**
12	RSSV-512	-1.100**	0.033	0.822*	15.022**	0.489**	3.923**	3.927**
13	RSSV-503	0.011	0.256	-0.067	2.244	0.663**	-1.342**	-1.338**
	SE(gi) ±	0.3007	0.5394	0.3409	1.5127	0.0337	0.2134	0.2241

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance.

Sr. No.	Name of parents	Cane harvest index (%)	Juice yield (lit/ha)	Brix (%)	Reducing sugar (%)	Total sugar (%)	Non-reducing sugar (%)	Ethanol yield (lit/ha)
	Female	8	9	10	11	12	13	14
1	CMS-185A	1.152 **	199.211**	-0.511**	0.001	0.012	0.011	11.889**
2	ICMS-479A	-1.172 **	-953.122**	-0.094	-0.096**	-0.871**	-0.785**	-98.644**
3	CMS-1409A	0.019	753.911**	0.606**	0.094**	0.859**	0.774**	86.756**
	SE ±	0.0741	50.1623	0.1098	0.0193	0.0472	0.0519	3.4356
	Male							
4	RSSV-542	-0.026 **	-937.856**	0.183	0.048	-1.167**	-1.218**	-110.244**
5	RSSV-260	4.067 **	4240.922**	-0.261	0.292**	0.756**	0.468**	301.867**
6	RSSV-509	0.526 **	2289.145**	1.294**	-0.108**	0.722**	0.853**	171.089**
7	RSSV-386	0.712 **	151.478	-0.150	-0.008	-0.433**	-0.418**	-5.133
8	RSSV-498	-2.238 **	-2069.078**	0.517*	-0.386**	0.367**	0.758**	-113.244**
9	RSSV-417	-1.813 **	-1645.967**	-0.817**	0.326**	0.722**	0.398**	-66.578**
10	RSSV-453	-0.789 **	-2168.078**	-1.261**	-0.197**	-0.411**	-0.228*	-153.911**
11	RSSV-313	-1.369 **	-1405.744**	0.406*	0.137**	-0.789**	-0.940**	-131.022**
12	RSSV-512	1.760 **	2122.811**	-0.261	0.159**	0.222*	0.043	142.867**
13	RSSV-503	-0.833 **	-577.633**	0.350	-0.263**	0.011	0.285**	-35.689**
	SE(gi) ±	0.1353	91.5835	0.2005	0.0352	0.0861	0.0947	6.2725

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance

Table 3: Specific combining ability (sca) effects for ancillary data, brix, cane yield, juice yield and its contributing traits in 30 crosses of sweet sorghum

Sr. No.	Crosses	Days to 50% flowering	Days to maturity	Internodes/plant	Plant height (cm)	Stem girth (cm)	Total biomass yield (t/ha)	Cane weight (t/ha)
1	CMS-185A x RSSV-542	-2.078**	-2.122*	0.189	-20.022**	0.161**	-1.040**	-1.044**
2	CMS-185A x RSSV-260	-4.078**	-4.122**	-0.367	-7.689**	0.091	-3.569**	-3.573**
3	CMS-185A x RSSV-509	1.700**	1.656	0.522	-2.133	0.759**	2.507**	2.503**
4	CMS-185A x RSSV-386	0.478	0.767	0.522	18.089**	1.270**	1.726**	1.722**
5	CMS-185A x RSSV-498	0.367	-0.011	-0.033	28.978**	0.601**	-0.038	-0.042
6	CMS-185A x RSSV-417	-1.078*	-0.789	0.633	-11.467**	0.136*	1.576**	1.585**
7	CMS-185A x RSSV-453	-2.411**	-2.122*	-0.589	-3.911	-1.150**	-1.828**	-1.818**
8	CMS-185A x RSSV-313	0.144	0.433	-0.256	20.089**	-0.640**	-1.125**	-1.116**
9	CMS-185A x RSSV-512	2.700**	3.433**	0.744	4.644	0.728**	1.635**	1.631**
10	CMS-185A x RSSV-503	4.256**	2.878**	-1.367*	-26.578**	-1.959**	0.157	0.153
11	ICMS-479A x RSSV-542	0.222	-0.589	-0.578	-4.089	1.250**	3.085**	3.101**
12	ICMS-479A x RSSV-260	4.222**	3.411**	1.200*	19.244**	0.390**	4.906**	4.922**
13	ICMS-479A x RSSV-509	-2.333**	-3.144**	0.089	14.467**	-0.202**	7.658**	7.674**
14	ICMS-479A x RSSV-386	1.11*	0.633	-0.244	-29.311**	-1.385**	-3.249**	-3.233**
15	ICMS-479A x RSSV-498	-1.33*	-0.478	0.533	-10.756**	-0.457**	3.174**	3.190**
16.	ICMS-479A x RSSV-417	0.222	0.744	-0.133	19.133**	-0.622**	0.514	0.503
17.	ICMS-479A x RSSV-453	2.889**	3.411**	-0.022	8.022**	1.165**	-1.723**	-1.733**
18.	ICMS-479A x RSSV-313	1.111*	1.633	0.311	-7.644**	0.572**	-2.030**	-2.041**
19.	ICMS-479A x RSSV-512	-2.667**	-3.033**	-1.356*	-18.422**	-1.424**	-3.860**	-3.884**
20.	ICMS-479A x RSSV-503	-3.444**	-2.589**	0.200	9.356**	0.713**	-8.475**	-8.499**
21.	CMS-1409A x RSSV-542	1.856**	2.711**	0.389	24.111**	-1.411**	-2.045**	-2.057**
22.	CMS-1409A x RSSV-260	-0.144	0.711	-0.833	-11.556**	-0.481**	-1.337**	-1.349**
23.	CMS-1409A x RSSV-509	0.633	1.489	-0.611	-12.333**	-0.557**	-10.165**	-10.177**
24.	CMS-1409A x RSSV-386	-1.589**	-1.400	-0.278	11.222**	0.114	1.524**	1.512**
25.	CMS-1409A x RSSV-498	0.967	0.489	-0.500	-18.222**	0.145*	-3.136**	-3.148**
26.	CMS-1409A x RSSV-417	0.856	0.044	-0.500	-7.667**	0.487**	-2.090**	-2.088**
27.	CMS-1409A x RSSV-453	-0.478	-1.289	0.611	-4.111	-0.016	3.550**	3.552**
28.	CMS-1409A x RSSV-313	-1.256*	-2.067*	-0.056	-12.444**	0.068	3.156**	3.157**
29.	CMS-1409A x RSSV-512	-0.033	-0.400	0.611	13.778**	0.695**	2.226**	2.254**
30.	CMS-1409A x RSSV-503	-0.811	-0.289	1.167	17.222**	1.245**	8.318**	8.346**
	S.E. (Sij) ±	0.5208	0.9342	0.5904	2.6202	0.0584	0.3697	0.3882
	C.D. 5%	1.0425	1.8700	1.1818	5.2448	0.1170	0.7399	0.7771

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance

Sr. No.	Crosses	Cane harvest index (%)	Juice yield (lit/ha)	Brix (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ethanol yield (lit/ha)
1	CMS-185A x RSSV-542	-0.563 *	-1955.211**	0.733*	-0.001	-0.423**	-0.424*	-128.889**
2	CMS-185A x RSSV-260	-1.543**	-761.322**	-0.489	-0.512**	-0.112	0.396*	-54.333**
3	CMS-185A x RSSV-509	1.101 **	1235.456**	-2.044**	0.354**	-0.579**	-0.925**	42.778**
4	CMS-185A x RSSV-386	0.585 *	1078.456**	-0.267	0.054	0.710**	0.682**	88.667**
5	CMS-185A x RSSV-498	0.039	635.678**	-0.933**	0.099	0.377*	0.282	56.111**
6	CMS-185A x RSSV-417	0.777 **	383.900*	0.400	0.221**	0.854**	0.622**	58.778**
7	CMS-185A x RSSV-453	-0.817**	-81.989	1.844**	0.010	-0.946**	-0.974**	-44.889**
8	CMS-185A x RSSV-313	-0.463	-973.656**	1.511**	-0.257**	0.266	0.527**	-39.778**
9	CMS-185A x RSSV-512	0.451	1294.122**	-0.156	0.254**	0.621**	0.355*	113.0**
10	CMS-185A x RSSV-503	0.434	-855.433**	-0.600	-0.223**	-0.768**	-0.541**	-91.444**
11	ICMS-479A x RSSV-542	1.507 **	609.122**	0.650	0.496**	-0.407**	-0.902**	12.644
12	ICMS-479A x RSSV-260	2.004 **	1561.678**	1.761**	0.218**	0.971**	0.741**	144.220**
13	ICMS-479A x RSSV-509	3.578 **	1965.122**	0.872*	-0.016	0.771**	0.777**	158.311**
14	ICMS-479A x RSSV-386	-1.294 **	-1387.544**	-0.683	-0.549**	-1.807**	-1.282**	-162.133**
15	ICMS-479A x RSSV-498	1.626 **	280.011	-0.017	0.129*	0.160	0.051	28.644*
16.	ICMS-479A x RSSV-417	0.237	-410.767*	-1.017**	-0.382**	-0.796**	-0.412*	-54.689**
17.	ICMS-479A x RSSV-453	-0.829 **	261.345	0.094	0.440**	1.438**	1.035**	82.644**
18.	ICMS-479A x RSSV-313	-1.073 **	1857.011**	-1.239**	-0.193**	-0.884**	-0.721**	62.756**
19.	ICMS-479A x RSSV-512	-1.442 **	-2369.878**	-0.572	-0.282**	-0.362*	-0.076	-171.133**
20.	ICMS-479A x RSSV-503	-4.315 **	-2366.100**	0.150	0.140*	0.916**	0.788**	-101.244**
21.	CMS-1409A x RSSV-542	-0.944 **	1346.089**	-1.383*8	-0.494**	0.830**	1.326**	116.244**
22.	CMS-1409A x RSSV-260	-0.460	-800.356**	-1.272**	0.294**	-0.859**	-1.137**	-89.867**
23.	CMS-1409A x RSSV-509	-4.679 **	-3200.578**	1.172**	-0.339**	-0.192	0.148	-201.089**
24.	CMS-1409A x RSSV-386	0.708 **	309.089	0.950**	0.494**	1.097**	0.599**	73.467**
25.	CMS-1409A x RSSV-498	-1.665 **	-915.689**	0.950**	-0.228**	-0.537**	-0.334*	-84.756**
26.	CMS-1409A x RSSV-417	-1.014 **	26.867	0.617	0.161*	-0.059	-0.211	-4.089
27.	CMS-1409A x RSSV-453	1.646 **	-179.356	-1.939**	-0.450**	-0.492**	-0.061	-37.756**

28.	CMS-1409A x RSSV-313	1.536 **	-883.356**	-0.272	0.450**	0.619**	0.194	-22.978*
29.	CMS-1409A x RSSV-512	0.991 **	1075.756**	0.728*	0.028	-0.259	-0.278	58.133**
30.	CMS-1409A x RSSV-503	3.881 **	3221.533**	0.450	0.083	-0.148	-0.247	192.689**
	S.E. (Sij) ±	0.2344	158.6272	0.3473	0.0610	0.1492	0.1640	10.8643
	C.D. 5%	0.4693	317.5260	0.6951	0.1222	0.2986	0.3283	21.7472

Note: * Significant at 5% level of significance, ** Significant at 1% level of significance

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