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Combining Ability Studies for Grain Yield and Its Component Traits in Sweet Corn (*Zea mays* var. *saccharata*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Using 15 sweet corn inbreds, a line x tester design was made to perform combining ability analysis for yield and its contributing traits. For every character under study, the interaction between Line x Tester was highly significant, with the exception of days to 50% tasseling. For every attribute studied, the variation resulting from sca exceeded the variance resulting from gca. Which indicates the presence of non-additive gene action between the parents. As a result of their high *per se* performance combined with high gca effects for the majority of the yield and yield contributing traits, such as ear weight without husk, number of kernels per row, total soluble solids, 100 kernel weight, cob yield per plot and total sugar, the lines L_6, L_{12} and testers T_1, T_2 were determined to be

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the best general combiners. The hybrid $L_3 \times T_1$, which had the highest *per se* performance and sca for cob yield per plot, 100 kernel weight and ear weight without husk, was determined to be the best hybrid out of the 36 hybrids examined.

Keywords: Sweet corn; combining ability; Line x Tester; gca; sca.

1. INTRODUCTION

Maize (*Zea mays*) is the poacea family cereal crop. The entire world now possesses maize since, it was extensively domesticated in Central America. Due to its adaptability it may be grown in temperate, subtropical and tropical areas [1]. In India it is primarily grown during kharif season, but certain states, such as Bihar, it has planted in both *kharif* and *rabi* seasons with the aim of good production and productivity.

According to *FAOSTAT* 2021-2022, Globally 193.70 million ha of land are planted with maize, producing 1147.70 million tonnes with a productivity of 5.75 tonnes / ha. In India 9.90 million hacters of land are under cultivation with the production of 31.50 million tonnes. Within that 0.64 million acres of corn fields are present in Bihar with the annual production of 3.34 million tonnes.

Sweet corn is a variant of normal corn with sweeter kernels that is consumed at the milky stage, which is harvested 24 days after pollination [2]. Sweet corn is consumed as fresh vegetable in many western countries and its fresh, canned and processed products are popular in many Asiatic countries including india. Sweetness of kernels are by the actions of few recessive genes. Multiple endosperm genes utilised in the enhancement of sweet corn have been identified to increase sugar content and diminish starch content [3,4,5]. There are four type of recessive mutant genes responsible for the sweetness of maximum available sweet corn genotypes were sugary1 (su_1), brittle (*bt*), sugary enhancer (*se*) and shrunken 2 (sh_2).

In order to conduct a methodical breeding programme, it is necessary to identify both the parents and the crosses that can be utilized to produce further genetic enhancement in crop output. The significance of gene action in each variable that contributes to yield is crucial in determining the most effective breeding method. Parental knowledge, which includes combining abilitie, is valuable for determining appropriate parents based on hybrid performance. With this background a study was conducted on sweet corn to evaluate the gene action and combining capacity of parents for important yield-contributing traits.

2. MATERIALS AND METHODS

In the study, a Line x Tester design was used to cross 12 lines and three testers of sweet corn during the *Rabi* 2022. Table 1 contains the list of lines and testers utilized in our current inquiry. The hand emasculation and pollination procedure was employed as the crossover technique. The seeds of 36 recently created hybrids, together with the fifteen original parents, were assessed using a Randomized Block Design (RBD) with three replications during *Kharif* 2023 at the Experimental Farm, TCA, Dholi, RPCAU. The entries were cultivated in two rows, each measuring 3 meters in length, with a spacing of 60 x 20 centimeters. This resulted in a plot size of 3.6 square meters. The recommended set of procedures was followed, and biometric observations were recorded on three randomly selected plants for 16 quantitative traits (days to 50% tasseling, days to 50% silking, chlorophyll concentration measured in SPAD units, plant height measured in centimeters, ear height measured in centimeters, ear weight with husk measured in grammes, ear weight without husk measured in grammes, husk ratio measured as a percentage, ear length measured in centimeters, ear girth measured in centimeters, number of rows per ear, number of kernels per row, 100 kernel weight measured in grammes, shelling percentage measured as a percentage, cob yield per plot measured in kilogrammes and fodder yield per plot measured in kilogrammes) and five quality traits (total soluble solids measured in °Bx, reducing sugar measured as a percentage, non-reducing sugar measured as a percentage, total sugar measured as a percentage and starch measured as a percentage). An analysis of variance was conducted for all the attributes using the model proposed by Panse and Sukhatme [6]. The analysis of Line Tester was conducted according to the procedure outlined by Kempthorne [7].

3. RESULTS AND DISCUSSION

The analysis of variance revealed substantial variations among the genotypes for all the variables examined (Table 2, 2a). The analysis of variance for combining ability revealed significant differences among line x testers for all traits, except for days to 50% tasseling. Additionally, there were significant differences among lines for all traits studied, indicating that the experimental material exhibited substantial variability (Table 3, 3a). The presence of substantial genetic diversity was indicated by the significant variances in the genotypes of all the characters [8]. Significant variance was seen among testers for 14 features, excluding husk ratio, ear length, total soluble solids, shelling percentage, non-reducing sugar, total sugar and starch. This signifies a divergence among the hybrids.

For the purpose of creating an effective plant breeding programme, plant breeders need to understand both additive and non-additive gene action. The combining ability analysis makes it possible to separate the hybrids genotypic variation into variations resulting from specific combining abilities (interaction effects) and general combining abilities (main effects). Previous researchers proposed that there would be a higher likelihood of establishing superior genotype in early segregating generations if additive genetic variation was higher. Selecting for subsequent generations is the best course of action if dominant and epistatic interactions are prevalent. The ratio of gca to sca is used to express it. Higher sca indicates the presence of non-additive gene action, primarily due to dominance and epistatic interactions, while larger general combining ability (gca) indicates a higher proportion of additive gene action.

The analysis of genotypes revealed that the sca variance exceeded the gca variance for all the characters studied. This indicates that a higher proportion of non-additive genes are responsible for the inheritance of these traits. It also suggests that heterosis breeding can be effectively utilized to harness hybrid vigour. Rodrigues et al. [9] Abdel et al. [10] and Sing and Roy [11] have observed similar findings. The degree of dominance was found to be less than one for all the features, except for ear height. This suggests that the parents have partial dominance over their hybrids whereas ear height degree of dominace was found more than unity, which indicates over dominace of hybrid (Table 4). The study revealed that parents exhibited varying levels of combining ability for different qualities. It was also shown that no single parent demonstrated exceptional combining ability for all attributes (Table 5, 5a).

Majumder and Bhowal [12] observed a correlation between the direct performance and general combining ability (gca) impacts in enhancing any given trait. Keeping this as the reference, lines L_6 and L_{12} as well as the testers T_1 and T_2, were identified as the best general combiners due to their high *per se* performance and high gca effects for various yield and yield contributing traits, such as ear weight without husk, number of kernels per row, total soluble solids, 100 kernel weight, cob yield per plot and total sugar. Ambikapathy et al. [13] also found some parents UMI 1200-7-25-1-6-1, VIM 61 and VIM 58 as a good general combiners for yield related traits. And L_5, L_6 and L_{12} were found to be best lines for improving total soluble solids and total sugars (Table 7). Abdallah [14] and Meseka and Ishaaq (2012) also found similar significant effects of strong general combining ability (GCA) on yield and yield attributing variables.

Specific combining ability is a useful tool for determining the most effective cross combination to maximize hybrid vigour. The cob yield per plot was very high in the L_3 x T_1 hybrid, indicating a specific combing ability. Out of the 36 hybrids, six hybrids exhibited substantial positive sca effects for cob yield per plot, as seen in Table 6, 6a, 6b. The hybrids $L_3 \times T_1$, $L_6 \times T_1$ and $L_7 \times T_2$ were discovered as excellent specific combiners and also demonstrated exceptional *per se* performance for cob yield per plot. The hybrid $L_3 \times T_1$ had the highest individual performance together with sca effects, for the following characteristics: ear weight without husk, 100 kernel weight and cob yield per plot. Some of the hybrids were found high mean and high sca for some of the traits *viz.,* ear weight without husk ($L_3 \times T_1$, $L_6 \times T_1$), ear length ($L_3 \times T_2$, $L_6 \times T_1$), ear girth ($L_2 \times T_3$, $L_3 \times T_2$), number of rows per ear ($L_1 \times T_2$), number of kernels per row ($L_4 \times T_1$), total soluble solids ($L_{12} \times T_3$, $L_6 \times T_1$) and 100 kernel weight ($L_8 \times T_1$, $L_3 \times T_1$) (Table 8). Reddy et al. [15] and Kumari et al. [16] also found high sca values for many plant characteristics, including plant height, ear height, ear length, ear circumference, kernel rows per ear, kernel per row, 100-seed weight and grain production per plant. The good sca effects observed may be attributed to a mix of favorable genes inherited from the corresponding parents, along with non-additive gene action [17-19].

Table 1. Parents used in the Line x Tester analysis

S. No.	Code No.	Name of the lines	Source
1	L_1	BSCH 416078	AAU, Godhra
2	L_2	BIO 4043	AAU, Godhra
3	L_3	FSCH 119	AAU, Godhra
4	L_4	MSCH 20	AAU, Godhra
5	L_5	KDM 1263	AAU, Godhra
6	L_6	DMSC 24	AAU, Godhra
7	L_7	MSCH 21	AAU, Godhra
8	L_8	MSCH 22	AAU, Godhra
9	L_9	SC 162	AAU, Godhra
10	L_{10}	DMSC 37-3	AAU, Godhra
11	L_{11}	I-07-37-1-5	AAU, Godhra
12	L_{12}	I-07-62-3-2	AAU, Godhra
Code No.		**Name of the testers**	
13	T_1	BSCH 416086	AAU, Godhra
14	T_2	Hawali Sugar	AAU, Godhra
15	T_3	I-07-37-4-1	AAU, Godhra

Table 2. Analysis of variance for different morphological traits

S. V.	Df	Mean sum of squres										
		DFT	DFS	CHL	PH	EH	EWH	EW	HR	EL	EG	NRPE
Treatments	50	7.66**	7.50**	90.97**	834.22**	61.96**	1397.62**	1004.82**	30.72**	5.88**	9.65**	4.33**
Replications	2	5.26	1.97	0.71	25.32	0.97	4.60	1.74	0.31	0.24	0.06	0.04
Error	100	1.64	1.60	1.50	20.80	2.48	6.84	5.78	0.26	0.11	0.10	0.01

Table 2a. Analysis of variance for different morphological traits (Contd.)

S. V.	Df	Mean sum of squres									
		NKPR	TSS	100KW	SP	CYP	FYP	RS	NRS	TS	ST
Treatments	50	9.59**	5.15**	47.66**	108.25**	0.79**	3.02**	0.22**	0.63**	1.54**	3.27**
Replications	2	0.05	0.20	0.14	4.22	0.01	0.02	0.01	0.01	0.17	0.05
Error	100	0.38	0.15	0.46	1.44	0.01	0.02	01	0.02	0.03	0.09

*** Significant at 1% level*

Table 3. Analysis of variance for combining ability for lines, testers and their crosses

S. V.	Df	Mean sum of squres										
		DFT	DFS	CHL	PH	EH	EWH	EW	HR	EL	EG	NRPE
Lines	11	8.88**	8.93**	162.56**	2405.33**	140.41**	2210.90**	1684.46**	42.59**	8.32**	11.77**	4.70**
Testers	2	9.33**	12.25**	361.44**	798.97**	91.30**	992.59**	819.50**	49.52	3.85	14.19**	9.33**
Lines×Testers	22	2.42	4.61**	24.63**	102.40**	5.65**	261.85**	151.59**	22.86**	1.82**	3.97**	2.42**
Error	100	1.74	1.61	1.50	20.80	2.47	6.84	5.78	0.26	0.10	0.10	0.08

Table 3a. Analysis of variance for combining ability for lines, testers and their crosses (Contd.)

S. V.	Df	Mean sum of squres									
		NKPR	TSS	100KW	SP	CYP	FYP	RS	NRS	TS	ST
Lines	11	11.90**	12.21**	80.69**	175.35**	1.32**	5.02**	0.43**	1.24**	3.11**	7.46**
Testers	2	16.33**	2.57	83.94**	49.44	0.64**	1.91**	0.62**	0.33	1.84	2.90
Lines×Testers	22	4.52**	2.84**	13.11**	77.16**	0.12**	0.45**	0.10**	0.38**	0.83**	1.31**
Error	100	0.25	0.15	0.46	1.44	0.01	0.02	0.01	0.02	0.03	0.09

*** Significant at 1% level*

Table 4. Estimates of general and specific combining ability variance, gene action and degree of dominance in sweet corn

S.No	Characters	σ^2gca	σ^2sca	σ^2gca /σ^2sca	σ^2A	σ^2D	σ^2A/ σ^2D	Degree of dominance
1	Days to 50% tasseling	0.076	0.458	0.166	0.152	0.458	0.332	0.576
2	Days to 50% silking	0.056	2.001	0.028	0.112	2.001	0.056	0.237
3	Chlorophyll content	1.971	15.420	0.128	3.942	15.420	0.256	0.506
4	Plant height	24.044	54.402	0.442	48.088	54.402	0.884	0.940
5	Ear height	1.4875	2.114	0.704	2.975	2.114	1.407	1.186
6	Ear weight with husk	20.6035	170.008	0.121	41.207	170.008	0.242	0.492
7	Ear weight without husk	16.372	97.203	0.168	32.744	97.203	0.337	0.580
8	Husk ratio	0.243	15.063	0.016	0.486	15.063	0.032	0.180
9	Ear length	0.068	1.143	0.059	0.136	1.143	0.119	0.345
10	Ear girth	0.0955	2.577	0.037	0.191	2.577	0.074	0.272
11	Number of rows per ear	0.0345	1.562	0.022	0.069	1.562	0.044	0.210
12	Number of kernels per row	0.094	2.845	0.033	0.188	2.845	0.066	0.257
13	TSS	0.092	1.796	0.051	0.184	1.796	0.102	0.320
14	100 Kernal weight	0.796	8.434	0.094	1.592	8.434	0.189	0.434
15	Shelling percentage	0.9215	50.476	0.018	1.843	50.476	0.037	0.191
16	Cob yield per plot	0.0125	0.076	0.164	0.025	0.076	0.329	0.574
17	Fodder yield per plot	0.0475	0.287	0.166	0.095	0.287	0.331	0.575
18	Reducing sugar	0.004	0.066	0.061	0.008	0.066	0.121	0.348
19	Non-reducing sugar	0.008	0.239	0.033	0.016	0.239	0.067	0.259
20	Total sugar	0.024	0.533	0.045	0.048	0.533	0.090	0.300
21	Starch	0.0635	0.812	0.078	0.127	0.812	0.156	0.395

Table 5. General combining ability (gca) effects of parents for yield and yield related traits

SV	DFT	DFS	CHL	PH	EH	EWH	EW	HR	EL	EG
Parents Lines:										
L1	-0.389	0.083	-9.299**	-7.932	-1.867	-17.431*	-14.666*	1.288	-1.536**	-1.618*
L2	-0.722	-0.917	-3.899*	-2.668	0.593	-22.059**	-18.710**	2.096*	-0.776	-1.508*
L3	0.611	0.750	-1.873	8.205	1.906	13.666	13.579*	-3.491**	0.818	0.949
L4	-1.722**	-1.583	3.284*	-11.545*	-4.864**	-0.969	-2.486	1.762	-1.049*	-1.094
L5	-0.389	-0.250	-0.903	23.155**	8.349**	-13.292	-11.272	0.885	-0.436	-0.821
L6	-0.056	0.083	6.611**	-12.345**	-0.981	21.698**	18.936**	-2.013*	1.248**	1.019
L7	1.611**	1.417	1.164	-4.645	-3.847*	-12.144	-11.472	3.128**	0.504	-0.354
L8	0.278	0.083	-0.983	2.225	-1.794	6.664	2.780	2.022*	-1.126**	-0.304
L9	0.611	0.417	3.951*	33.518**	6.326**	10.196	9.837	-2.151*	0.444	1.546*
L10	1.611**	1.750	0.357	-25.318**	-1.651	-6.766	-4.882	-0.884	1.118**	0.206
L11	-0.722	-0.917	-2.276	8.322	0.743	-6.001	-4.768	-0.075	-0.062	0.259
L12	-0.722	-0.917	3.867*	-10.972*	-2.914	26.438**	23.124**	-2.567*	0.851*	1.722**
CD 5%	**1.151**	**1.984**	**3.036**	**9.166**	**3.253**	**15.138**	**12.698**	**1.984**	**0.833**	**1.250**
CD 1%	**1.523**	**2.626**	**4.018**	**12.132**	**4.307**	**20.036**	**16.806**	**2.626**	**1.103**	**1.654**
Testers:										
T1	0.111	0.063	3.867*	1.953	-0.713	4.435*	3.607*	-0.406	-0.377	-0.588*
T2	-0.556	-0.583	2.199	3.421	1.824	1.363	1.803	-0.916	0.203	-0.074
T3	0.444	0.583	-3.632*	-5.373	-1.111	-5.798**	-5.410**	1.322	0.174	0.661*
CD 5%	**1.746**	**1.984**	**3.492**	**8.491**	**2.857**	**4.206**	**2.976**	**1.329**	**0.496**	**0.516**
CD 1%	**2.311**	**2.626**	**4.621**	**11.239**	**3.781**	**5.567**	**3.939**	**1.759**	**0.657**	**0.683**

DFT, Days to 50% Tasseling; DFS, Days to 50% Silking; CHL, Chlorophyll content; PH, Plant Height; EH, Ear Height; EWH, Ear Weight with Husk; EW, Ear Weight without Husk; HR, Husk Ratio; EL, Ear Length; EG, Ear Girth

Table 5a. General combining ability (gca) effects of parents for yield and yield related traits (Contd.)

SV	NRPE	NKPR	TSS	100KW	SP	CYP	FYP	RS	NRS	TS	ST
Parents Lines											
L1	-0.611	-2.194*	-1.713**	-2.471*	-5.617**	-0.410*	-0.757*	-0.253**	-0.425**	-0.677**	-0.690**
L2	-1.278*	-1.194	-0.999**	-3.354**	-4.562**	-0.523**	-0.984**	-0.099	-0.272*	-0.373*	-0.798**
L3	0.722	-0.194	0.367	3.699**	2.753	0.381*	0.740*	0.086	0.225	0.308	-0.133
L4	-0.611	-0.194	-0.523	-1.998	-7.188**	-0.071	-0.435	0.075	0.067	0.141	0.408
L5	0.056	-0.528	1.627**	-3.271**	-2.050	-0.315	-0.586	-0.202**	-0.411**	-0.613**	-0.454
L6	0.722	1.472	1.841**	3.089*	3.368*	0.531**	1.012**	0.358**	0.527**	0.886**	1.859**
L7	-0.611	0.806	-0.333	-3.527**	-1.615	-0.321	-0.578	-0.200**	-0.283*	-0.482**	-0.191
L8	0.722	-0.528	0.811*	2.336	5.468**	0.075	0.128	0.228**	0.342**	0.570**	1.330**
L9	0.722	0.139	-0.986**	3.899**	6.478**	0.276	0.587	0.100	0.265*	0.367*	0.239
L10	-0.611	0.472	-0.133	-1.124	-1.456	-0.136	-0.228	-0.034	0.021	-0.017	-0.737**
L11	0.056	-0.194	-1.159**	-0.264	1.580	-0.133	-0.203	-0.319**	-0.523**	-0.839**	-1.257**
L12	0.722	2.139*	1.201**	2.986*	1.580	0.648**	1.303**	0.260**	0.466**	0.728**	0.423
CD 5%	**1.131**	**2.063**	**0.694**	**2.420**	**3.234**	**0.357**	**0.714**	**0.139**	**0.238**	**0.357**	**0.476**
CD 1%	**1.497**	**2.731**	**0.919**	**3.203**	**4.280**	**0.473**	**0.945**	**0.184**	**0.315**	**0.473**	**0.630**
Testers:											
T1	-0.444	0.722	0.306	1.204**	0.618	0.101*	0.103	-0.088	-0.074	-0.160	-0.252
T2	0.556	-0.611	-0.184	0.513**	0.733	0.051	0.161	-0.063	-0.034	-0.098	-0.056
T3	-0.111	-0.111	-0.123	-1.718**	-1.352	-0.152**	-0.264**	0.151	0.108	0.259	0.308
CD 5%	**0.873**	**1.032**	**0.634**	**0.357**	**3.214**	**0.079**	**0.198**	**0.218**	**0.615**	**0.853**	**1.368**
CD 1%	**1.155**	**1.631**	**0.840**	**0.473**	**4.254**	**0.105**	**0.263**	**0.289**	**0.814**	**1.129**	**1.812**

NRPE, Number of Rows Per Ear; NKPR, Number of Kernels per Row; TSS, Total Soluble Solids; 100KW, 100 Kernel Weight; SP, Shelling percentage; CYP, Cob Yield per Plot; FYP, Fodder Yield per Plot; RS, Reducing Sugar; NRS, Non-Reducing Sugar; TS, Total Sugar; ST, Starch

** Significant at 5% level ** Significant at 1% level*

Table 6. Specific combining ability (sca) effects of hybrids for yield and yield related traits

CROSSES	DFT	DFS	CHL	PH	EH	EWH	EW
L1×T1	-1.111**	-1.333**	-0.610	-0.863	-0.190	-12.168**	-10.727**
L1×T2	0.556**	0.250	-2.276*	-0.531	-0.958	6.453*	4.917
L1×T3	0.556**	1.083**	2.885**	1.393	1.148	5.715	5.811*
L2×T1	0.222	-0.333	-3.710**	-4.186	0.120	-3.297	-2.883
L2×T2	-1.111**	-0.750	3.244**	-0.744	-0.678	-2.339	-1.279
L2×T3	0.889**	1.083*	0.465	4.930	0.558	5.636	4.162
L3×T1	-0.111	0.044	-3.846**	-0.159	-0.164	17.872**	15.868**
L3×T2	-0.444*	-0.417	3.298**	-4.528	-1.351	-8.960**	-7.248**
L3×T3	0.556**	0.417	0.549	4.687	1.515*	-8.912**	-8.620**
L4×T1	0.222	1.333**	0.787	-0.479	-0.284	4.408	3.103
L4×T2	-0.111	-0.083	1.021	-4.888	2.089**	3.931	2.717
L4×T3	-0.111	-1.250**	-1.808*	5.367	-1.805*	-8.339**	-5.820*
L5×T1	-1.111**	-1.000*	1.314	5.871*	0.333	-8.343**	-4.721
L5×T2	1.556**	2.583**	-1.362	2.602	0.346	-0.306	-1.677
L5×T3	-0.444*	-1.583**	0.049	-8.473**	-0.679	8.649**	6.398*
L6×T1	-0.444*	-0.333	1.450	-0.729	0.823	9.596**	7.550**
L6×T2	0.222	-0.750	3.014**	-1.098	-0.624	-10.248**	-8.526**
L6×T3	0.222	1.083*	-4.465**	1.827	-0.199	0.652	0.976
L7×T1	0.889**	1.333**	3.917**	-1.119	0.700	-10.159**	-8.222**
L7×T2	0.556**	-0.083	-2.249*	6.102*	-0.698	11.065**	9.642**
L7×T3	-1.444**	-1.250**	-1.668	-4.983	-0.002	-0.906	-1.421
L8×T1	-0.778**	-1.333**	2.954**	-1.919	-3.404**	12.305**	2.516
L8×T2	0.889**	1.250**	-2.092*	8.262**	1.609*	-0.733	3.440
L8×T3	-0.111	0.083	-0.861	-6.343*	1.795*	-11.572**	-5.957*
L9×T1	0.889**	0.333	-0.750	-7.513**	0.776	-0.599	-0.990
L9×T2	-0.444*	-0.083	-1.766	8.059**	-0.941	0.583	0.783
L9×T3	-0.444*	-0.250	2.515**	-0.547	0.165	0.016	0.208
L10×T1	0.889**	1.000*	-0.856	2.394	-0.137	-6.865*	-3.311
L10×T2	-0.444*	-0.417	-0.912	-8.064**	1.096	-4.308	-3.169
L10×T3	-0.444*	-0.583	1.769	5.670*	-0.959	11.172**	6.481*
L11×T1	0.222	0.667	-0.633	7.664**	1.100	-2.350	0.975
L11×T2	-1.111**	-1.750**	-2.269*	-3.614	-0.208	2.852	0.046
L11×T3	0.889**	1.083	2.902**	-4.050	-0.892	-0.502	-1.020
L12×T1	0.222	-0.333	-0.016	1.037	0.326	-0.400	0.842
L12×T2	-0.111	0.250	2.348*	-1.561	0.319	2.009	0.354
L12×T3	-0.111	0.083	-2.331*	0.523	-0.645	-1.610	-1.196
CD 5%	**0.417**	**0.838**	**1.786**	**5.615**	**1.389**	**5.773**	**4.940**
CD 1%	**0.551**	**1.108**	**2.363**	**7.432**	**1.838**	**7.642**	**6.539**

DFT, Days to 50% Tasseling; DFS, Days to 50% Silking; CHL, Chlorophyll content; PH, Plant Height; EH, Ear Height; EWH, Ear Weight with Husk; EW, Ear Weight without Husk

Table 6a. Specific combining ability (sca) effects of hybrids for yield and yield related traits (Contd.)

CROSSES	HR	EL	EG	NRPE	NKPR	TSS	100KW
L1×T1	2.725**	0.264	-1.469**	-0.222	-1.722**	-0.173	-1.691*
L1×T2	-0.578	0.574**	-0.533*	0.778	0.611	0.127	0.590
L1×T3	-2.147**	-0.838**	2.002**	-0.556	1.111**	0.046	1.101
L2×T1	0.889	-0.156	-1.049**	0.444	0.278	-0.076	-2.287**
L2×T2	-1.423**	-0.386*	-1.023**	-0.556	-1.389**	-0.076	-0.917
L2×T3	0.534	0.542**	2.072**	0.111	1.111**	0.153	3.204**
L3×T1	-1.120*	-0.739**	-0.156	0.444	0.278	-0.033	2.999**
L3×T2	0.140	0.881**	1.310**	-0.556	0.611	2.037**	-1.180
L3×T3	0.980	-0.141	-1.155**	0.111	-0.889**	-2.004**	-1.819**

CROSSES	HR	EL	EG	NRPE	NKPR	TSS	100KW
L4×T1	0.619	-0.483*	-0.902**	-0.222	3.278**	-1.013**	-2.304**
L4×T2	0.559	-0.163	0.614*	0.778	-1.389**	0.257	1.047
L4×T3	-1.179*	0.646**	0.289	-0.556	-1.889**	0.756**	1.258*
L5×T1	-3.337**	-1.206**	0.724**	-0.889*	-0.389	0.487*	-0.411
L5×T2	2.285**	0.174	0.260	0.111	0.944**	-0.103	-0.920
L5×T3	1.052*	1.032**	-0.985**	0.778	-0.556	-0.384	1.331*
L6×T1	0.872	0.781**	0.184	0.444	0.611	0.964**	0.269
L6×T2	0.148	0.601**	-0.390	-0.556	-1.056**	-1.546**	-0.350
L6×T3	-1.020	-1.381**	0.205	0.111	0.444	0.583*	0.081
L7×T1	0.369	-0.036	1.308**	-0.222	-0.722*	0.687**	-2.534**
L7×T2	-2.178**	-0.756**	0.374	0.778	0.611	0.127	3.147**
L7×T3	1.809**	0.792**	-1.681**	-0.556	0.111	-0.814**	-0.613
L8×T1	6.419**	0.934**	0.218	0.444	-0.389	-0.026	3.502**
L8×T2	-3.101**	-0.916**	0.414	-0.556	-0.056	0.464*	-1.747**
L8×T3	-3.319**	-0.018	-0.631*	0.111	0.444	-0.437	-1.756**
L9×T1	0.801	0.194	-0.082	0.444	-1.056**	0.350	0.319
L9×T2	-0.190	0.314	-0.076	-0.556	1.278**	-0.720**	0.700
L9×T3	-0.611	-0.508**	0.159	0.111	-0.222	0.369	-1.019
L10×T1	-3.080**	-0.309	1.298**	-0.222	-0.389	-0.433	0.319
L10×T2	-0.668	-0.089	-0.006	-1.222**	-0.056	-0.443	0.803
L10×T3	3.747**	0.399*	-1.291**	1.444**	0.444	0.876**	-1.019
L11×T1	-4.170**	0.071	0.324	-0.889*	0.278	-0.576*	2.623**
L11×T2	3.452**	-0.039	-0.730**	2.111**	-0.389	0.854**	-0.907
L11×T3	0.718	-0.031	0.405	-1.222**	0.111	-0.277	-1.716**
L12×T1	-0.989	0.687**	-0.399	0.444	-0.056	-0.156	-0.718
L12×T2	1.554**	-0.193	-0.213	-0.556	0.278	-0.976**	-0.267
L12×T3	-0.565	-0.494*	0.612*	0.111	-0.222	1.133**	0.984
CD 5%	**1.051**	**0.377**	**0.496**	**0.838**	**0.645**	**0.456**	**1.190**
CD 1%	**1.392**	**0.499**	**0.657**	**1.108**	**0.867**	**0.604**	**1.576**

HR, Husk Ratio; EL, Ear Length; EG, Ear Girth; NRPE, Number of Rows Per Ear; NKPR, Number of Kernels per Row; TSS, Total Soluble Solids; 100KW, 100 Kernel Weight

Table 6b. Specific combining ability (sca) effects of hybrids for yield and yield related traits (Contd.)

CROSSES	SP	CYP	FYP	RS	NRS	TS	ST
L1×T1	-2.632**	-0.300**	-0.604**	0.025	-0.071	-0.042	-0.339
L1×T2	3.034**	0.137	0.281*	-0.056	-0.192*	-0.244*	0.235
L1×T3	-0.402	0.163*	0.324*	0.030	0.263**	0.286*	0.104
L2×T1	-1.263	-0.081	-0.137	-0.136**	-0.231**	-0.366**	0.439*
L2×T2	-8.289**	-0.036	-0.094	0.020	0.101	0.122	0.463*
L2×T3	9.552**	0.117	0.231	0.116*	0.130	0.245**	-0.901**
L3×T1	0.279	0.445**	0.801**	-0.170**	-0.421**	-0.591**	-0.393*
L3×T2	`1.034	-0.203**	-0.373**	0.189**	0.341**	0.530**	0.098
L3×T3	-1.313	-0.241**	-0.428**	-0.019	0.080	0.060	0.294
L4×T1	0.336	0.086	-0.103	-0.099	-0.130	-0.230	0.453*
L4×T2	0.335	0.076	0.469**	-0.014	0.092	0.078	0.060
L4×T3	-0.671	-0.162*	-0.366**	0.113*	0.037	0.151	-0.513**
L5×T1	-2.875**	-0.132	-0.249	0.161**	0.318**	0.477**	-0.655**
L5×T2	2.297*	-0.047	-0.126	-0.070	-0.083	-0.152	0.119
L5×T3	0.578	0.179*	0.375**	-0.091	-0.235**	-0.325**	0.535**
L6×T1	0.493	0.212**	0.335*	-0.172**	-0.153	-0.328**	-1.011**
L6×T2	-1.670	-0.239**	-0.472**	0.143**	0.439**	0.586**	0.676**
L6×T3	1.177	0.027	0.137	0.029	-0.286**	-0.258*	0.335
L7×T1	-4.056**	-0.230**	-0.352**	-0.158**	-0.340**	-0.494**	-0.028

CROSSES	SP	CYP	FYP	RS	NRS	TS	ST
L7×T2	7.305**	0.270**	0.405**	0.191**	0.259**	0.454**	-0.554**
L7×T3	-3.249**	-0.040	-0.053	-0.033	0.081	0.040	0.582**
L8×T1	7.112**	0.069	0.164	-0.042	-0.018	-0.062	-0.289
L8×T2	-9.253**	0.099	0.206	0.013	0.115	0.126	0.115
L8×T3	2.142*	-0.168*	-0.369**	0.029	-0.097	-0.064	0.174
L9×T1	-0.033	-0.028	0.025	0.275**	0.419**	0.694**	1.282**
L9×T2	2.731**	0.022	-0.007	-0.379**	-0.749**	-1.132**	-0.534**
L9×T3	-2.698**	0.006	-0.018	0.104*	0.330**	0.438**	-0.748**
L10×T1	0.679	-0.092	-0.142	0.190**	0.277**	0.468**	0.227
L10×T2	-1.553	-0.089	-0.210	0.169**	0.229**	0.393**	-0.375*
L10×T3	0.874	0.182*	0.352**	-0.359**	-0.506**	-0.861**	0.148
L11×T1	2.005*	0.028	0.107	-0.016	0.040	0.020	0.557**
L11×T2	6.388**	0.001	-0.048	0.063	-0.314**	-0.362**	-0.875**
L11×T3	-8.393**	-0.029	-0.059	0.063	0.274**	0.341**	0.318
L12×T1	-0.045	0.024	0.156	0.142**	0.311**	0.453**	-0.243
L12×T2	-2.358*	0.010	-0.031	-0.159**	-0.240**	-0.400**	0.572**
L12×T3	2.402*	-0.033	-0.125	0.017	-0.071	-0.053	-0.329
CD 5%	**1.964**	**0.139**	**0.258**	**0.100**	**0.159**	**0.238**	**0.357**
CD 1%	**2.600**	**0.184**	**0.341**	**0.131**	**0.210**	**0.315**	**0.473**

SP, Shelling percentage; CYP, Cob Yield per Plot; FYP, Fodder Yield per Plot; RS, Reducing Sugar; NRS, Non-Reducing Sugar; TS, Total Sugar; ST, Starch

** Significant at 5% level ** Significant at 1% level*

Table 7. List of top performing parents based on mean performance and gca

S. No.	Characters	Mean		Gca		Mean and gca	
		Lines	Testers	Lines	Testers	Lines	Testers
1	Ear weight without husk (g)	L_{12}(128.8), L_6(125.1)	T_1(60.4), T_2(56.0)	L_{12}(23.1**), L_6(18.9**)	T_1(3.6*)	L_{12}, L_6	T_1
2	Ear length (cm)	L_4(15.4), L_8 (14.5)	T_3(11.9), T_2(11.4)	L_6(1.2**), L_{10}(1.1**)	-	-	-
3	Ear girth (cm)	L_3(14.2), L_4 (14.1)	T_2(9.1), T_1(8.6)	L_{12}(1.7**), L_9(1.5**)	T_3(0.6*)	-	-
4	Number of rows per ear	L_3(14), L_4 (14)	T_1(10), T_2(10)	-	-	-	-
5	Number of kernels per row	L_7(20), L_{12} (20)	T_1(15), T_3(15)	L_{12}(2.13)	-	L_{12}	-
6	Total soluble solids (°Bx)	L_6(16.2), L_5 (15.2)	T_3(14.1), T_2(13.2)	L_6(1.8**), L_5(1.6**)	-	L_6,L_5	-
7	100 kernel weight (g)	L_{12}(32.6), L_6 (31.3)	T_2(19.4), T_1(18.9)	L_9(3.9**), L_3(3.7**)	T_1(1.2**), T_2(0.5**)	-	T_1,T_2
8	Cob yield per plot (kg)	L_{12}(3.6), L_6 (3.5)	T_1(1.7), T_2(1.6)	L_{12}(0.6**), L_6(0.5**)	T_1(0.1*)	L_{12}, L_6	T_1
9	Total sugars (%)	L_9(8.1), L_{12} (8)	T_3(7.7), T_2(6.6)	L_6(0.5**), L_{12}(0.5**)	-	L_{12}	-

The cob yield per plot in the L_3×T_1 combination was mostly influenced by the high general combining ability of the parent L_3, whereas the parent T_1 had a lower general combining ability. Therefore, the large yield could be attributed to the dominance or epistatic impact of a single inbred. Three hybrid combinations, specifically L_6×T_2, L_9×T_1 and L_3×T_2 exhibited excellent individual performance and demonstrated favorable specific combining ability (sca) for total sugars [20,21].

Table 8. List of top performing hybrids based on mean performance and sca

S.No.	Characters	Mean	Sca	Mean and Sca
1	Ear weight without husk (g)	$L_3 \times T_1$(113.2),$L_6 \times T_1$(110.3) $L_{12} \times T_1$(107.8),$L_{12} \times T_2$(105.5)	$L_3 \times T_1$(15.9**),$L_7 \times T_2$(9.6**) $L_6 \times T_1$(7.6**),$L_{10} \times T_3$(6.5**)	$L_3 \times T_1$, $L_6 \times T_1$
2	Ear length (cm)	$L_6 \times T_2$(16.1),$L_3 \times T_2$(15.9) $L_{10} \times T_3$(15.8),$L_6 \times T_1$(15.8)	$L_5 \times T_3$(1**),$L_8 \times T_1$(0.9**) $L_3 \times T_2$(0.9**),$L_6 \times T_1$(0.8**)	$L_3 \times T_2$, $L_6 \times T_1$
3	Ear girth (cm)	$L_{12} \times T_3$(14.7),$L_2 \times T_3$(12.9) $L_9 \times T_3$(14),$L_3 \times T_2$(14)	$L_2 \times T_3$(2.1**),$L_1 \times T_3$(2**) $L_3 \times T_2$(1.3**),$L_7 \times T_1$(1.3**)	$L_2 \times T_3$, $L_3 \times T_2$
4	Number of rows per ear	$L_{11} \times T_2$(14),$L_3 \times T_1$(12) $L_6 \times T_1$(12),$L_8 \times T_1$(12)	$L_{11} \times T_2$(2.1**),$L_{10} \times T_3$(1.4**) $L_5 \times T_3$(0.8**),$L_7 \times T_2$(0.8**)	$L_{11} \times T_2$
5	Number of kernels per row	$L_4 \times T_1$(21),$L_6 \times T_1$(20) $L_{12} \times T_1$(20),$L_{12} \times T_2$(19)	$L_4 \times T_1$(3.3**),$L_9 \times T_2$(1.3**) $L_1 \times T_3$(1.1**),$L_2 \times T_3$(1.1**)	$L_4 \times T_1$
6	Total soluble solids (°Bx)	$L_6 \times T_1$(17.2),$L_{12} \times T_3$(16.3) $L_5 \times T_1$(16.54),$L_3 \times T_2$(16.3)	$L_3 \times T_2$(2**),$L_{12} \times T_3$(1.1**) $L_6 \times T_1$(0.9**),$L_{10} \times T_3$(0.9**)	$L_{12} \times T_3$, $L_6 \times T_1$
7	100 kernel weight (g)	$L_3 \times T_1$(30.1),$L_8 \times T_1$(29.3) $L_9 \times T_1$(27.6),$L_9 \times T_2$(27.3)	$L_8 \times T_1$(3.5**),$L_2 \times T_3$(3.2**) $L_7 \times T_2$(3.1**),$L_3 \times T_1$(3**)	$L_8 \times T_1$, $L_3 \times T_1$
8	Cob yield per plot (kg)	$L_3 \times T_1$(3.2),$L_6 \times T_1$(3.1) $L_{12} \times T_1$(3),$L_7 \times T_2$(2.2)	$L_3 \times T_1$(0.4**),$L_7 \times T_2$(0.3**) $L_6 \times T_1$(0.2**),$L_5 \times T_3$(0.2**)	$L_3 \times T_1$, $L_6 \times T_1$ $L_7 \times T_2$
9	Total sugars (%)	$L_6 \times T_2$(8.9),$L_9 \times T_3$(8.6) $L_9 \times T_1$(8.4),$L_3 \times T_2$(8.2)	$L_9 \times T_1$(0.7**),$L_6 \times T_2$(0.6**) $L_3 \times T_2$(0.5**),$L_5 \times T_1$(0.5**)	$L_6 \times T_2$, $L_9 \times T_1$ $L_3 \times T_2$

4. CONCLUSION

Parents L_6 and L_{12} along with tester T_1 were identified as effective general combiners based on their strong performance and genetic combining ability for yield-related variables (Table 7). Among the 36 hybrids examined, the hybrid $L_3 \times T_1$ was determined to be the superior hybrid due to its highest individual performance and specific combining ability for cob yield per plot, 100 kernel weight and ear weight without husk.

Followed by hybrids $L_6 \times T_1$ and $L_7 \times T_2$ were also identified as best hybrids which recorded high field performance coupled with high sca effect for ear weight without husk, ear length, cob yield per plot and total soluble solids (Table 8). All these hybrids could be commercialized after extensive yield trial.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

I (Rajasekar) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of my manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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