

Study on Combining Ability for Yield and Yield Contributing Characters of Short Statured Maize Inbred Lines at over Locations

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Abstract

Twenty short-statured maize inbred lines were collected from CIMMYT India and Mexico through the Plant Breeding Division, Bangladesh Agricultural Research Institute (BARI), Gazipur. The experiment was conducted from November 2020 to April 2021 in three different agroecological regions such as BARI, Gazipur, RARS Barisal and RARS Rangpur. Seven inbred lines were selected on the basis of genetic diversity and per se performance and they were crossed separately in a 7 × 7 half diallel fashion, producing 21F₁ hybrids in 2019 which were evaluated at three locations. However, variances due to GCA were much higher in magnitude than SCA for all the characters indicating preponderance of additive gene effects on the inheritance of these characters. Two parents viz., P₃ (CML33) and P₄ (CML41) were good general combiners and two crosses viz., P₄ × P₅ (CML41 × CML31) and P₅ × P₇ (CML31 × CML124) expressed significant positive SCA effects coupled with significant positive heterosis for grain yield and for most of the yield contributing characters over the two commercial check varieties BHM 9 and NK40. Four crosses: P₁ × P₅ (CML116 × CML31), P₁ × P₆ (CML116 × CML32), P₂ × P₆ (CML72 × CML32) and P₃ × P₄ (CML33 × CML41), exhibited significant and negative SCA effects for both plant and ear height which were desirable for short stature. Genotypes × location interaction was also significant for maximum characters, suggesting that genotypes interacted significantly in different environments.

Keywords

Combining Ability, GCA, SCA, Gene Action, Maize

1. Introduction

Maize (*Zea mays* L., $2n = 20$) ranks as the third most important cereal crop next to wheat and rice in production in the world. Maize is suitable to diverse environments though it is native to Central America. The crop expands new areas and environments continuously and thus, it explores Asia. The demand of maize increased gradually during nineties with the expansion of the poultry industry and this is why maize yields increased from an average of less than 1 ton per hectare for several decades through 1992 to more than 6 tons per hectare in 2010 by the introduction of hybrid maize varieties, still it is in increasing trend rapidly. Maize yields per hectare in Bangladesh exceed yields in China and Japan [1]. The increase in net income from hybrids can be estimated by assuming that farmers replace wheat with maize [2]. An earlier estimate in the world, maize production recorded 875 million tons [3], while 23 lac tons has been produced in Bangladesh, which occupies an area of 3.5 lac hectares [4] with tremendous growth till now. [5] reported that the present production of maize was around 57 lac tons in the area of 5.52 lac hectares with an average yield 10.20 tons/ha. About 30% of world production is used for direct human consumption and as an industrial input, while 70% is used as animal feed [6]. But in Bangladesh, the sole maize (except popcorn and adulteration in wheat flour) is used up by poultry industries. In these circumstances, we, the people of Bangladesh should change our food habits by taking maize directly because both nutritional and medicinal value of maize is higher than rice and wheat. Ones upon a time, there was no hybrid maize variety in Bangladesh to meet the challenge, now Bangladesh Agricultural Research Institute (BARI) has developed some hybrid maize varieties with the help of the International Maize and Wheat Improvement Centre (CIMMYT).

Combining ability estimation is considered an important genetic attribute for maize breeders in anticipating improvement in productivity via hybridization and selection [7]. The value of inbred lines in the commercial production of hybrid maize being determined by two factors, the characteristics of the inbred itself with respect to yielding potentiality, pollen shedding, disease resistance etc., and the behaviour of the line in hybrid combinations as well [8]. To determine GCA and SCA information of white grain maize germplasm for identification of nature of genes action involved in the expression of their quantitative traits, genetic diversity evaluation, suitable parental lines selection for hybridization, heterotic pattern classification, heterosis estimation, and hybrids development, the present investigation was undertaken as the above information can be achieved only by combining ability study [9]-[12]. So, the investigation was carried out to observe the combining ability performances over locations and to select the short statured

hybrids.

2. Materials and Methods

The experiment was conducted during November 2020 to May 2021 at three different locations *i.e.* Bangladesh Agricultural Research Institute (BARI) Gazipur and two different regional stations *i.e.*, Regional Agricultural Research Stations (RARS) Rahmatpur, Barisal and Burirhat, Rangpur with 21 F₁s and 2 commercial hybrids viz., BHM9 and NK40 as check. Gazipur belongs to Agro Ecological Zone (AEZ) no. -28 (Madhupur Tract), Barisal -AEZ 18 (Young Meghna Estuarine Floodplain), Rangpur -AEZ 28 (North Eastern Barind Tract). Twenty maize inbred lines were collected from CIMMYT India, CIMMYT Mexico and Plant Breeding Division of BARI. The pedigree were as follows CML20-2-B (H08R-N8205-4), CML27-2-B (H08R-N8205-7), CML28-2-B (H08R-N8205-9), CML30-2-B (H08R-N8205-13), CML31-2-B (H08R-N8205-15), CML32-2-B (H08R-N8205-17), CML33-1-B (H08R-N8205-18), CML41-2-B (H08R-N8205-20), CML51-2-B (H08R-N8205-22), CML58-1-B (H08R-N8205-23), CML70-2-B (H08R-N8205-28), CML71-2-B (H08R-N8205-31), CML72-1-B (H08R-N8205-32), CML112-1-B (H08R-N8205-38), CML113-1-B (H08R-N8205-39), CML116-1-B (H08R-N8205-42), CML121-1-B (H08R-N8205-43), CML122-1-B (H08R-N8205-44), CML124-1-B (H08R-N8205-45), CML124-2-B (H08R-N8205-46). Among them the following inbreds CML31-2-B, CML32-2-B, CML33-1-B, CML41-2-B, CML72-1-B, CML116-1-B, CML124-2-B were selected and renamed as P05, P06, P03, P04, P02 and P01 during hybridization. Following 7 × 7 diallel fashion 21 F₁s were developed in 2019. In every location three separate experiments conducted following balanced alpha lattice design with 3 replications to determine the magnitude of G × E interaction and select stable genotypes across different environments. Each plot comprised of 2 rows 5.0 m long. Spacing adopted was 60 × 20 cm between rows and hills, respectively. One healthy seedling per hill was kept after proper thinning. Fertilizers were applied @ 250, 55, 110, 40, 5 and 1.5 kg/ha of N, P, K, S, Zn, B respectively. Standard agronomic practices were followed and plant protection measures were taken as and when required. Data on days to 50% pollen shedding and silking were recorded on whole plot basis. Ten randomly selected plants were used for recording observations on plant height and ear height. All the plants in 2 rows were considered for plot yield which was later converted to ton per hacter (t/ha). Data were analyzed using Crop stat 7.2 and MS Excel.

3. Results and Discussion

3.1. Mean Performances of 21 F₁ Hybrids of Short Statured Maize Inbred Lines

Results of overall mean performance across 3 locations of the crosses are presented in **Table 1**. Considering grain yield across locations, two crosses P₃ × P₅ and P₅ × P₇ out yielded (11.24 & 11.28 t/ha) the check hybrid NK40 (11.02 t/ha) and BHM9 (11.22 t/ha). This was followed by P₄ × P₇ (10.89 t/ha) and P₁ × P₄ (10.77

t/ha). Days to tasseling and silking, ranged, from 92.01 to 98.88 and 98.53 to 105.4 days. Plant height was found highest in $P_5 \times P_7$ (172.5 cm) and lowest in $P_2 \times P_6$ (73.23 cm). Ear height was found highest in $P_3 \times P_6$ (64.24 cm) and lowest in $P_2 \times P_6$ (21.73 cm). Ear length and diameter ranged from 11.02 to 16.62 and 4.37 to 5.70 cm respectively. While 1000-kernel wt. ranged from 322.7 to 413.71 gm.

3.2. Analysis of Variance (ANOVA) for Combining Ability 21 F_1 Hybrids of Short Statured Maize Inbred Lines

The mean sum of square obtained from combined analysis of variance showed the presence of genetic variability among the crosses and environment for all the characters under study except ear length (Table 2). This indicated the influence of differential environmental factors at different locations on the expression of different characters on short statured maize. Crosses \times Environment interaction was also highly significant for all the characters. From the result, it can be concluded that the short statured maize genotypes responded significantly to the environments for yield and other yield-contributing characters.

Combined analysis of variances for combining ability for short-statured maize revealed that general combining ability (GCA) were significant for all the characters except plant height and ear length and specific combining ability (SCA) variance was non-significant for all the characters. Variances due to GCA were much higher in magnitude than SCA for all the characters indicating preponderance of additive gene effects for the inheritance of these traits. Both GCA and SCA effects showed significant interaction with environment for all the traits. This suggested the need of selecting different parental lines for hybrids for different ecological situations. [13] observed that GCA variance was highly significant for grain yield, ear length and diameter and no. of kernel/rows.

The ratio components of GCA to SCA revealed that GCA was higher than SCA for all the parameters except ear diameter (ED) which indicated additive genetic variances among the traits. [14] observed additive genetic variance in ear height, [15] in ear length, [16] in yield components, [17] in days to tasseling, days to silking, plant height, ear height and thousand seed weight.

Table 1. Mean performances of 21 crosses for yield and yield contributing characters of short statured maize inbred lines over three environments during rabi 2020-21.

Cros.	DT (50%)	DS (50%)	EH (cm)	PH (cm)	EL (cm)	ED (cm)	R/C	S/R	TGW	GY (t/h)
$P_1 \times P_2$	97.50	103.00	38.11	97.99	11.02	4.69	13.86	17.68	360.50	6.430
$P_1 \times P_3$	95.10	100.25	58.60	143.30	14.59	5.25	13.86	31.22	394.80	9.43
$P_1 \times P_4$	92.01	98.88	57.50	145.30	14.76	5.26	14.56	36.05	412.10	10.77
$P_1 \times P_5$	98.88	104.71	25.47	86.31	11.67	4.58	13.86	22.88	353.6	5.967
$P_1 \times P_6$	97.16	104.03	29.42	85.63	11.26	4.58	13.86	20.81	358.78	6.77
$P_1 \times P_7$	97.50	102.31	31.24	104.90	13.82	5.08	14.56	26.69	357.06	7.35
$P_2 \times P_3$	93.39	100.60	53.80	137.5	13.53	5.24	15.94	33.28	413.71	10.15

Continued

P ₂ × P ₄	92.36	99.56	46.35	128.10	12.98	4.90	14.56	25.65	350.22	6.96
P ₂ × P ₅	96.48	101.62	33.99	92.15	11.26	4.69	13.17	23.22	374.20	6.35
P ₂ × P ₆	98.19	105.31	21.73	73.23	11.05	4.35	14.56	18.02	351.91	6.99
P ₂ × P ₇	98.53	105.40	25.44	86.72	11.19	4.76	12.48	18.72	351.91	6.75
P ₃ × P ₄	92.35	98.88	50.81	138.00	13.53	5.40	14.56	26.34	367.36	8.19
P ₃ × P ₅	94.42	100.25	58.95	144.10	13.39	5.54	14.56	27.73	369.08	11.24
P ₃ × P ₆	95.44	101.62	64.24	143.80	13.32	5.17	13.17	31.2	377.66	9.21
P ₃ × P ₇	95.79	103.34	55.72	136.90	15.93	5.45	14.56	36.05	382.81	10.30
P ₄ × P ₅	92.35	98.53	58.47	165.10	13.66	5.06	14.56	29.46	333.03	8.81
P ₄ × P ₆	93.38	100.6	30.55	115.5	13.94	4.97	13.86	28.77	367.36	9.32
P ₄ × P ₇	92.72	98.88	46.00	138.21	13.63	5.07	15.25	29.81	375.95	10.89
P ₅ × P ₆	97.50	103.68	40.31	108.60	14.21	4.76	14.56	27.04	343.30	7.01
P ₅ × P ₇	95.79	101.62	63.03	172.50	16.62	5.70	14.56	31.8	322.7	11.28
P ₆ × P ₇	97.16	102.65	27.36	85.52	10.78	4.37	13.86	21.84	326.16	6.48
BHM9	95.79	103.00	73.95	157.41	14.42	4.92	13.86	24.96	412.00	11.22
NK40	97.16	104.03	77.69	177.82	18.06	5.24	15.25	38.48	362.21	11.02
F-test	**	**	**	**	**	ns	*	**	**	*
Mean	95.86	102.24	43.88	119.14	13.04	4.88	14.07	27.08	342.13	7.78
CV (%)	1.7	2.1	19.3	12.1	11.7	2.33	7	17.1	9.4	13.1
LSD (0.05)	2.6	3.44	13.86	23.59	2.49	0.56	1.60	7.55	52.79	1.63

*, ** and ns indicate 5%, 1% level of significance and nonsignificant respectively; Checks: i) NK40 (commercial hybrid), ii) BHM 9 (BARI hybrid maize 9). DT = Days to Tasseling (50%), DS = Days to Silking (50%), PH = Plant Height (cm), EH = Ear Height (cm), EL = Ear Length (cm), ED = Ear Diameter (cm), R/C = Rows per Cob, S/R = Seeds per Row, TGW = Thousand Grains Weight (gm) and GY = Grain Yield (t/h).

Table 2. ANOVA to test combining ability for yield and yield contributing characters of short statured maize hybrids over three environments during rabi 2020-21.

SV	df	DT (50%)	DS (50%)	PH (cm)	EH (cm)	EL (cm)	ED (cm)	R/C	S/R	TGW	GY (t/h)
Env (E)	2	56.00**	67.65**	42279.3**	18895.1**	15.21	12.43**	151.1**	77.266**	5754.14	39.93**
Crosses	27	51.58**	91.45**	3955.1**	2607.50**	16.77	11.96**	8.45**	336.93**	7818.44**	16.10
Cross × E	54	10.20**	21.83**	1034.3**	491.15**	10.25**	8.12**	5.64**	40.17**	2401.72**	10.92**
GCA	6	110.44**	227.99**	9114.71	6886.81**	33.72	23.21**	8.53**	500.3**	17818.6**	43.88**
SCA	21	15.91	32.94	1743.70	773.51	9.51	29.32	8.43	290.25	3532.67	4.20
GCA × E	12	9.08**	21.94**	1300.10**	603.09**	15.02**	13.30**	102.2**	42.53**	2079.19**	17.64**
SCA × E	42	12.00**	21.78**	920.45**	443.17**	8.20**	9.11**	52.16**	12.43**	2539.94**	8.04**
Residuals	162	1.49	2.14	153.18**	149.30	3.33	2.705	11.671	42.341	545.21	1.96

*P ≤ 0.05, **P ≤ 0.01 and SV = Source of variation; DT = Days to Tasseling (50%), DS = Days to Silking (50%), PH = Plant Height (cm), EH = Ear Height (cm), EL = Ear Length (cm), ED = Ear Diameter (cm), R/C = Rows per Cob, S/R = Seeds per Row, TGW = Thousand Grains Weight (gm) and GY = Grain Yield (t/h).

3.3. General Combining Ability (GCA) Effects 21 F₁ Hybrids of Short Statured Maize Inbred Lines

Parents P₁, P₃ and P₄ showed significant and negative GCA for days to pollen shedding and silking. For days to tasseling, negative estimates were considered desirable as those were observed to be associated with earliness. So, use of these four parents might be useful in developing early hybrid variety(s). [17] observed significant negative variances in case of two inbreds. [18] [19] observed the importance of additive genetic effects in controlling early maturity and yield.

Parents P₂, P₆ and P₇ exhibited significant and negative GCA effect both for plant and ear height. So, use of these three parents might be useful in developing short statured hybrid variety(s). The characteristics of a line along with the behaviour should be considered in the production of hybrid maize [20] [21] mentioned that earliness was associated with days to silking and the shorter plants as well. For grain yield (t/ha), both parents P₃, P₄ and P₇ showed significant and positive GCA effect. In addition to grain yield, parent P₃ and P₄ were also good general combiners, respectively, for thousand grain weight, ear length and ear diameter (Table 3). Ear diameter, ear length, thousand seed weight were recorded as good general combiners in the study of [17] [22] [23].

3.4. Specific Combining Ability (SCA) Effects 21 F₁ Hybrids of Short Statured Maize Inbred Lines

For grain yield (t/ha), the crosses P₁ × P₃, P₄ × P₅, P₅ × P₆ and P₅ × P₇ exhibited significant positive SCA effects. Significant and negative SCA effects for days to pollen shedding and silking are desirable for early maturing hybrids. Many of the crosses (P₂ × P₃, P₂ × P₄, P₂ × P₅, P₄ × P₅, P₄ × P₆, P₄ × P₇, P₅ × P₆ and P₅ × P₇) exhibited significant negative SCA effects for days to pollen shedding and silking. Four crosses (P₁ × P₅, P₁ × P₆, P₂ × P₆ and P₃ × P₄) exhibited significant and negative SCA effects for both plant and ear height and were desirable for exploiting non additive gene. In case of ear length, only one cross (P₃ × P₆), expressed significant and positive SCA effect. The cross (P₂ × P₇) exhibited positive and non-significant SCA effects. Four crosses (P₃ × P₇, P₄ × P₆, P₅ × P₆ and P₅ × P₇) showed significant and positive SCA effects for two major yield contributing characters; ear length and ear diameter (Table 4).

Normally the GCA effects do reflect in the SCA effects of the crosses in most of the studied traits as stated in the findings of [22] [24] [25]. Good general combining parents may not show high SCA effects in their hybrid combinations [26]. However, [16] [27] observed high estimates of SCA from high GCA parents. [28] reported positive relationship between SCA effects of kernels yield and yield contributing characters [29] suggested that both additive and non additive effects are important in controlling the expression of grain yield and days to silking though on additive effects were more important in controlling grain yield than in determining days to silking in their studies. The SCA was more highlighted than the GCA in the studies of [30].

Table 3. Estimates of general combining ability effects (GCA) of the parents for yield and yield contributing characters of short statured maize inbred lines over three environments during rabi 2020-21.

Parents	DT (50%)	DS (50%)	EH (cm)	PH (cm)	EL (cm)	ED (cm)	R/C	S/R	TGW	GY (t/h)
P ₁	-0.3915*	-0.677*	0.9653	1.435	0.47*	0.33*	0.05	1.223*	3.66	-0.328**
P ₂	0.5344*	0.693*	-17.31**	-5.14**	-0.80**	-0.35*	-0.31*	-3.3**	1.45	-0.396**
P ₃	-0.91**	-0.973**	16.25**	10.977**	1.34**	1.00**	0.22	3.5**	19.93**	0.5535**
P ₄	-1.984**	-1.714**	18.93**	4.432**	0.73**	0.30*	0.59**	3.06**	5.476	0.61**
P ₅	0.942**	0.656*	2.51	0.446	-0.90**	-0.33*	-0.09	-1.31*	-11.61*	-0.042
P ₆	1.164**	1.545**	-16.07**	-7.85**	-1.09**	-0.89**	-0.24	-2.52**	-8.067	-0.654**
P ₇	0.6455**	0.471	-5.28*	-4.30**	0.23	-0.05	-0.22	0.65	8.84*	0.26**
SE (gi)	0.1546	0.2037	1.4793	0.8747	0.1559	0.1042	0.1019	0.449	3.3315	0.0661
LSD (0.05)	0.378	0.498	3.62	2.14	0.381	0.255	0.25	1.1	8.16	0.1617
LSD (0.01)	0.573	0.755	5.484	3.243	0.578	0.386	0.378	1.664	12.350	0.245

*P ≤ 0.05, **P ≤ 0.01; DT = Days to Tasseling (50%), DS = Days to Silking (50%), PH = Plant Height (cm), EH = Ear Height (cm), EL = Ear Length (cm), ED = Ear Diameter (cm), R/C = Rows per Cob, S/R = Seeds per Row, TGW = Thousand Grains Weight (gm) and GY = Grain Yield (t/h).

Table 4. Specific combining ability effects (SCA) of 21 crosses for yield and yield contributing characters of short statured maize inbred lines over three environments during rabi 2020-21.

Crosses	DT (50%)	DS (50%)	EH (cm)	PH (cm)	EL (cm)	ED (cm)	R/C	S/R	TGW	GY (t/h)
P ₁ × P ₂	1.50**	0.806	-0.83	0.316	-1.41**	-0.48	0.08	-6.57**	16.07	0.31
P ₁ × P ₃	0.611	-0.194	9.58*	4.1	-0.09	-0.19	-0.34	-0.466	30.91*	2.72**
P ₁ × P ₄	-1.31**	-0.78	8.80*	9.57**	0.70	0.56*	-0.04	4.633	62.04**	-2.00**
P ₁ × P ₅	2.426**	2.51**	-31.97**	-17.54**	-0.68	-0.83**	-0.14	-3.663**	22.23	-0.23
P ₁ × P ₆	0.537	0.954	-14.07**	-5.41*	-0.89*	-0.28	0.01	-4.454**	23.80*	-0.68
P ₁ × P ₇	1.389**	0.361	-6.10	-7.20**	0.26	0.35	0.77**	-0.65	24.80*	-0.70
P ₂ × P ₃	-1.98**	-1.23*	22.29**	6.01*	0.16	0.46	1.91**	6.052**	51.47**	-0.60
P ₂ × P ₄	-1.91**	-1.49**	10.44**	5.32*	0.23	0.16	0.20	-0.85	4.14	0.205
P ₂ × P ₅	-0.833*	-1.86**	-8.05*	-2.70	0.19	0.19	-0.45	1.2	44.55**	0.25
P ₂ × P ₆	0.611	0.92	-7.83*	-6.30**	0.18	-0.27	1.03**	-2.602*	19.457	-1.045**
P ₂ × P ₇	1.463**	1.99**	-5.52	-6.25**	-1.00*	0.10	-0.98**	-3.8**	22.01	0.35
P ₃ × P ₄	-0.463	-0.491	-13.48**	-6.454**	-1.38**	0.27	-0.33	-6.97**	2.10	-0.645
P ₃ × P ₅	-1.39**	-1.53**	8.83*	5.421*	0.12	1.30**	0.35	-1.27	21.07	1.40**
P ₃ × P ₆	-0.611	-1.10*	27.18**	18.85**	0.23	0.81**	-0.83**	3.275**	25.864*	-1.64**
P ₃ × P ₇	-2.31**	-2.45**	26.58**	11.50**	0.99*	0.61*	-0.02	0.83	0.20	-0.644
P ₄ × P ₅	0.241	1.66**	9.623*	7.032**	1.46**	0.75**	0.49	6.2**	33.531**	3.05**
P ₄ × P ₆	-1.53**	-1.34*	-3.03	-7.30**	1.45**	0.90**	-0.54*	1.37	30.21*	-1.56**
P ₄ × P ₇	-1.68**	-1.93**	8.14*	4.143	-0.17	0.35	0.78**	0.51	41.54**	-1.71**
P ₅ × P ₆	-0.463	-0.64	6.68	6.148*	3.35**	0.93**	0.81**	4.1**	23.852*	1.00**

Continued

$P_5 \times P_7$	-1.61**	-1.639**	57.93**	24.66**	4.36**	2.81**	0.80**	6.88**	26.85*	2.2**
$P_6 \times P_7$	-0.5	-1.53**	-7.93*	-1.67	-1.12**	-0.50	0.28	-1.577	6.64	-0.53
SE (ij)	0.3827	0.5042	3.661	2.165	0.386	0.26	0.2521	1.1113	8.254	0.1636
LSD (0.05)	0.8	1.052	7.636	4.516	0.805	0.538	0.5258	2.32	23.6	0.84
LSD (0.01)	1.0888	1.434	10.415	6.16	1.1	0.734	0.717	3.1616	32.14	0.9654

* $P \leq 0.05$, ** $P \leq 0.01$; DT = Days to Tasseling (50%), DS = Days to Silking (50%), PH = Plant Height (cm), EH = Ear Height (cm), EL = Ear Length (cm), ED = Ear Diameter (cm), R/C = Rows per Cob, S/R = Seeds per Row, TGW = Thousand Grains Weight (gm) and GY = Grain Yield (t/h).

4. Conclusions

GCA effects showed wide range of variability among the parents. For all the characters none of the parents were found to be a good general combiner but P_3 and P_4 (CML33 and CML41) were found to be good general combiner for maximum characters. P_3 , P_4 and P_7 (CML33, CML41 and CML124) showed significant and positive GCA effect for grain yield, parents P_3 and P_4 (CML33 and CML41) were also good general combiner respectively, for thousand grain weights, ear length and ear dia. So, these two parents; P_3 and P_4 (CML33 and CML41) could be selected in hybrid breeding program with a view to increase the yield level.

Considering SCA the crosses; $P_1 \times P_3$ (CML116 \times CML33), $P_4 \times P_5$ (CML41 \times CML31), $P_5 \times P_6$ (CML31 \times CML32) and $P_{5X} \times P_7$ (CML31 \times CML124) exhibited significant and positive effects for grain yield (t/ha). These crosses involved both low \times high and high \times high general combining parents and produced significant positive SCA. Four crosses; $P_1 \times P_5$ (CML116 \times CML31), $P_1 \times P_6$ (CML116 \times CML32), $P_2 \times P_6$ (CML72 \times CML32) and $P_3 \times P_4$ (CML33 \times CML41), exhibited significant and negative SCA effects for both plant and ear height which are desirable for short stature. The crosses; $P_2 \times P_3$ (CML72 \times CML33), $P_2 \times P_4$ (CML72 \times CML41), $P_2 \times P_5$ (CML72 \times CML31), $P_4 \times P_5$ (CML41 \times CML31), $P_4 \times P_6$ (CML41 \times CML32), $P_4 \times P_7$ (CML41 \times CML124), $P_5 \times P_6$ (CML31 \times CML32) and $P_5 \times P_7$ (CML31 \times CML124) exhibited significant and negative SCA effects for days to pollen shedding and silking which are desirable for selection of early maturing hybrids. Two crosses; $P_4 \times P_5$ (CML41 \times CML31) and $P_1 \times P_3$ (CML116 \times CML33) exhibited maximum significant and positive SCA effects for grain yield (t/ha). $P_4 \times P_5$ (CML33 \times CML31) also showed standard heterosis over two checks at 1% level. These crosses need to be further evaluated in large plot and in wider agro-climatic conditions.

Conflicts of Interest

There was no conflict of interests.

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