Comparison among three different testers for the evaluation of new maize inbred lines (*Zea mays* L.)

Mohammad Reda Ismail[2,3]* Ali A El-Hosary[1] and Mahmoud El M El-Badawy[1]

[1]Agronomy Department, Faculty of Agriculture, Benha University, Egypt.
[2] Division of Genetics, Indian Agricultural Research Institute, New Delhi, India
[3] Field Crops Research Institute, Agricultural Research Center, Egypt.
* Corresponding author: E-mail: Breeder82@live.com

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Abstract

This study aimed to evaluate twenty elite yellow maize inbred lines as well as the suitable tester among three different. The elite inbred lines were crossed as female parents with three testers as male parents, i.e.Gem.Pop. (Broad genetic base), Single cross 101(Narrow genetic base) and Inbred line 100 (Narrow genetic base) at the Experiment Research Station of Moshtohor, Benha University, Egypt during 2014 growing summer season. The resulting 60 top crosses with three commercial check hybrids *i.e.* SC.155, SC. Pioneer 3080 and TWC.352 were evaluated in a yield trail in two sowing dates during 2015 growing summer season. Each experiment was laid out in randomized complete block design with three replications. The recommended packages of agronomic practices were followed to achieve a good yield. The morphological and agronomical evaluated traits included ear diameter (ED), number of rows per ear (NRE), number of kernels per row (NKR), 100-kernel weight (100KW) and grain yield per acre (1 hectare= 2.5 acre) (GYPA). The results showed significant mean square for sowing dates for all traits except for (NRE) and (NKR). The parental inbred lines (L-4, L-5, L-10, L-12, L-13, L-14 and L-19) possessed high GCA effects for grain yield. The inbred tester resulted the best combiner among the testers and expressed the best SCA effect over all crosses. Therefore, inbred line or single cross tester is preferred as it may permit quicker utilization of new lines in commercial hybrids especially if the tester is already in commercial use.

Introduction

Maize (*Zea mays* L.) is the third most important cereal in the world after wheat and rice. It ranks the top in grain yield per unit area of land, and its demand is expected to surpass that of wheat and rice by 2020 Odiyoet *al*., (2014). Maize provides over 20% of total calories in human diet in 21 countries, and over 30% in 12 countries. In Egypt, it is essential for human consumption as well as livestock. In addition, it is also used for industrial purposes such as manufacturing starch and cooking oils. In 2016 the corn grown area in Egypt was 0.75 Million hectares with an annual grain production of 6 Million metric tons and an average productivity of 8 ton per hectare. Yet, Egypt imports around 7-8 million ton of corn every year to tackle the gap between production and consumption (USDA 2018). Many efforts are devoted nowadays to increase the productivity through genetical improvement. The top cross method of maize breeding has been used to evaluate inbred lines for general combining ability (GCA) and specific combining ability (SCA). Davis (1927), Jenkins (1935) and Sprague (1939) suggested the method of early testing. Partition of the total combining ability effects of the lines into GCA and SCA was initiated by Sprague and Tatum (1942). Line × tester analysis is a modification of this method in which several testers are used Kempthorne (1957), which provides good information on the general and specific combining ability effects of parents and their hybrid combinations. Line × tester technique has been widely used in maize by several researchers like, El-Ghonemy (2015), Gamea (2015), Hassanet al (2016) and Ismail et al (2018) who estimated general and specific combining ability of grain yield and some other characteristics. The objectives of this study aimed to provide information of suitable testers for testing inbred lines, estimate of combining ability effects of some yellow maize inbred lines, and their interactions with sowing dates and identify the most superior lines and single crosses to be used in hybrid maize breeding programs.

Materials and Methods

The field experiments were conducted at the Experiment Research Station of Moshtohor, Benha University, Al-Qalyubiyah Governorate, Egypt during 2014 and 2015 summer season.

Plant materials

Twenty yellow maize inbred lines were developed by at Department of Agronomy, Faculty of Agriculture, Benha University by Prof. Dr. Ali Abd El-Maksoud El-Hosary and were used as female parent. Three testers of yellow maize were used as male parents to make all possible line × tester crosses. i.e. Gem. Pop., representing broad genetic base, Single cross 101 representing approximately narrow genetic base and the Inbred line 100 representing narrow genetic base. Three check varieties were used in this investigation, named: Single cross Giza 155 (SC.155), Single cross Pioneer 3080 (SC.3080) and three-way cross Giza 352(TWC.352).

Field experiments

Top cross constitution

In summer season 2014, the twenty inbred lines and the three testers were split sown on 25th May, 30th May and 8th June to avoid differences in flowering time and to secure enough hybrid seed. All possible top crosses combinations were made between the twenty inbred lines and three testers by hand method giving a total of 60 top crosses.In summer season 2015 two adjacent experiments were conducted on two sowing dates. i.e. 1^{st} May and 15^{th} May. In each experiment the twenty inbred lines, three testers, 60 top crosses as well as the three check hybrids (Single cross SC.155, Single cross SC. Pioneer 3080 and three-way cross TWC.352) were grown in a randomized complete block design with three replications. Each plot consisted of two ridges of 5 m length and 70 cm width. Each hill was spaced 25 cm apart. The recommended packages of agronomic practices were followed to achieve a good growth.

Morphological and agronomical traits

In this study, the following traits were evaluated:

1- Ear diameter (ED) (cm); 2- Number of rows/ear (RWR); 3- Number of Kernel/ row (NKR); 4- 100 kernel weight (100KW); 5- grain yield per acre (GYPA), was estimated and adjusted at 15.5% grain moisture and expressed in Kilo gram (kg) per acre (1 hectare= 2.5 acre) of maize grains.

Statistical analyses

Analysis of variance (ANOVA) according to Steel & Torrie (1980) Bartlett test was used to test the homogeneity of error variance among sowing dates for all studied traits. Analysis of general combining ability (GCA) and specific combining ability (SCA) was carried out following the method of Kempthorne (1957).Heterosis was calculated for each individual top cross as the percent deviation of F_1 mean performance from either SC.155, Pioneer 3080 and TWC. 352 average values for each experiment as well as the combined data.

Table 1 - Mean squares for ear diameter (ED), number of rows per ear (NRE), number of kernels per row (NKR), 100-Kernel weight (100KW) and grain yield per acre (GYPA) of combined analysis across two sowing dates (2015 growing season).

SOV (Sources of Variation)	d.f	Mean squares				
		ED (cm)	NRE	NKR	100KW (g)	GYPA (kg)
Sowing Dates (SD)	1	8.62**	1.21 ns	8.04 ns	1858.68**	75977.37**
Rep/SD	4	0.22	0.19	8.29	2.03	51.16
Crosses (C)	59	0.16**	5.58**	23.64**	62.46**	925.39**
Lines (L)	19	0.28**	10.82**	35.56**	98.76**	733.38**
Testers (T)	2	0.21*	34.37**	19.73 ns	117.07**	962.21**
Lines × Testers	38	0.10 ns	1.45**	17.88**	41.44**	1019.46**
Crosses × SD	59	0.09 ns	1.03**	13.50**	27.26**	1063.07**
Lines × SD	19	0.10 ns	1.11**	17.11**	24.36**	1361.00**
Testers × SD	2	0.34**	0.47 ns	24.79*	23.82**	2131.00**
Lines × Testers × SD	38	0.07 ns	1.02**	11.11 ns	28.88**	857.90**
Pooled error	236	0.07	0.53	7.79	2.56	37.17
GCA		-0.0001	0.31	0.00	1.03	-15.36
SCA		0.005	0.07	1.13	2.09	26.93
GCA × SD		-0.001	0.24	0.001	0.52	-2.35
SCA × SD		0.0001	0.16	1.11	8.77	273.58

ns * and ** indicate insignificant, significant at 0.05 and 0.01 probability levels, respectively.

Results and discussion

Significance of Mean Squares

Combined mean squares due to Line × Tester analyses over sowing dates are presented in (Table 1). Sowing dates mean squares were significant for all traits except number of rows/ear and number of kernels/row, indicating over all differences between the two sowing dates. These results are in harmony with those obtained by El-Hosary and El-Badawy (2005) and El-Hosary et al. (2006). Crosses mean squares were highly significant for all the studied traits, indicating the wide diversity between the parental materials used in the present study and the crosses were sufficiently different from each other for the studied traits.

Significant crosses × Sowing dates mean squares were obtained for all the studied traits except for ear diameter, revealing that the tested crosses ranked differently from sowing date to another. Mean squares due to lines, testers and line × tester resulted significant for all traits except Tester mean squares for number of kernels per row and line × tester mean square for ear diameter. Significant line × sowing dates for all the studied traits except for ear diameter. Insignificant tester × sowing dates mean squares was detected for number of rows per ear. Significant interaction lines × tester × sowing dates mean squares were obtained for all the studied traits, except for ear diameter and number of kernels per row. In addition, tester mean squares were much higher than those of lines mean squares for all studied traits, except for ear diameter and number of kernels per row. Such results revealed that testers contributed much more to the total variation as compared to lines.

Mean performance

Mean performance of the 60 top crosses along with the three check hybrids (SC.155, SC.3080 and TWC.352) for all the studied traits is presented in (Table 2).

Seven top crosses i.e. T_1× L7, T1× L13, T1× L17, T2× L4, T2× L5, T2× L10 and T2× L12 were significantly outyielded the best check hybrid SC.3080 (3410 kg/fed) for grain yield trait. Therefore, it could be utilized for future breeding work as well as for direct release after confirming the stability of their performances observed in the current study. The cross T1× L13 did not differ significantly with the best check hybrids SC. 3080 for ear diameter. While for number of rows/ear, four crosses viz. T1 × L13, T2 × L5, T3 × L5 and T3 × L6 exhibited significant higher than the best check hybrid (TWC.352). The two crosses T3× L12 (37.60) and T2× L11 (37.60) had the best value for number of kernels per row in comparison to the best check hybrid SC.3080. Regarding to100-kernel weight, the top crosses T1 × L1, T1 × L7, T1 × L12, T2 × L3, T2 × L15, T3 × L3 and T3 × L19 significantly surpassed the best check hybrid SC.155.

Combining ability effects

Results in (Table 1) indicated that σ^2 SCA was more important than σ^2 GCA for all studied traits except for number of rows/ear. These results indicated that the largest part of the total genetic variability associated with those traits was the result of non-additive type of gene action. The magnitude of the interaction between specific combining ability and sowing dates was much higher than that of general combining and sowing dates for all traits except number of rows/ear. These results led to the conclusion that non-additive gene action was more biased by the interaction with environments than the additive effects.

General Combining ability effect

The general combining ability effects (GCA) of testers and parental inbred lines for all traits is presented in (Table 3).

Five inbred lines i.e. (L1, L3, L9, L13 and L19) and the tester T-1 (L-100) expressed significant positive GCA effects (favorable) for ear diameter trait. Moreover, both inbred lines L13 and L19 were the best combiners for this trait. For number of rows per ear, the parental inbred lines L4, L5, L6, L13 and the tester T-3 (Gem. Pop) were considered to be the best combiners. For number of kernels per row, only two inbred line i.e. L11 and L12 showed significant positive GCA effects (favorable). The best general combiners which had significant positive GCA effects (favorable) were L1, L3, L8, L10, L12, L15, L20 and the Tester T-1 (L-100) for 100- kernel weight. Significant positive GCA effects (favorable)were obtained by the tester T-1 (L-100) and seven inbred lines (L4, L5, L10, L12, L13, L14, and L19) for grain yield. Hence, it could be concluded that these inbred lines would be of great values in breeding programs for improving grain yield. In view of this, the Tester T1 (L-100) was the best tester for ear diameter, 100-kernel weight and grain yield.

Specific combining ability effects

Specific combining ability effects (SCA) of the top crosses for all traits is presented in (Table 3).Significant positive SCA effects (favorable) for ear diameter were recorded by the top cross T2×L12. Regarding to number of rows per ear, five top crosses i.e. T_1×L13, T2×L4, T2×L6, T3×L3 and T3×L10 exhibited significant positive SCA effects (favorable). It was clear that T-2 (SC.101) was the best amongst the tester for this trait. Four top crosses (T1×L5, T1×L16, T2×L15 and T2×L20) gave si-

Table 2 - Mean performance of 60 top crosses as well as three check hybrids for all the studied traits, combined across two sowing dates.

Trait	ED (cm)			NRE			NKR			100KW (g)			GYPA (kg)		
Lines	Testers			Testers			Testers			Testers			Testers		
	T-1	T-2	T-3	T-1	T-2	T-3	T-1	T-2	T-3	T-1	T-2	T-3	T-1	T-2	T-3
L-1	4.60	4.38	4.53	13.92	14.83	15.13	34.47	34.37	33.72	36.50	31.00	28.67	3202	2940	3080
L-2	4.34	4.22	4.35	13.77	14.30	14.90	34.58	33.32	34.23	29.17	30.00	26.33	2633	2513	2832
L-3	4.25	4.15	4.32	12.75	12.48	14.35	34.67	34.62	35.83	35.50	37.00	37.83	2947	3009	2778
L-4	4.23	4.43	4.33	14.47	15.42	14.47	33.72	34.60	37.07	29.83	28.67	29.33	2862	3485	3067
L-5	4.42	4.47	4.47	15.28	16.33	16.47	35.33	33.13	30.03	29.33	29.00	28.17	3114	3468	2825
L-6	4.28	4.50	4.60	13.62	15.98	16.23	34.07	31.45	34.43	28.83	29.17	30.17	2908	3000	3185
L-7	4.43	4.20	4.00	13.33	13.77	14.70	34.87	33.07	34.32	36.00	29.33	26.50	3518	2733	2821
L-8	4.42	4.22	4.20	12.98	13.18	13.65	35.42	33.18	33.67	35.50	30.33	29.83	3277	2888	2989
L-9	4.52	4.38	4.63	13.17	14.35	14.05	32.82	32.60	36.12	31.00	29.50	28.83	2747	2506	3067
L-10	4.18	4.32	4.17	12.35	13.52	14.92	33.82	33.43	31.87	30.50	33.83	34.67	2874	3528	3324
L-11	4.20	4.08	4.12	13.17	14.22	14.12	36.08	37.60	35.43	26.00	26.67	27.83	2787	2978	3160
L-12	4.27	4.48	4.17	14.10	13.88	15.27	35.83	37.25	37.72	37.83	31.83	27.17	2915	3791	2715
L-13	4.63	4.48	4.45	16.48	16.10	15.90	33.45	33.10	32.57	29.17	32.17	33.67	3836	3048	2869
L-14	4.28	4.35	4.20	14.02	14.32	14.23	32.92	31.35	32.82	33.83	31.67	29.50	3272	3163	2941
L-15	4.48	4.38	4.38	14.07	14.35	15.47	31.30	36.67	34.87	31.33	37.00	30.17	2947	2810	3192
L-16	4.62	4.30	4.28	13.93	14.57	14.93	33.75	25.55	32.52	33.50	29.67	29.17	3160	2437	2954
L-17	4.62	4.23	4.60	14.35	14.08	15.10	34.75	32.20	33.57	33.33	27.33	30.83	3597	2435	3142
L-18	4.55	4.22	4.60	14.00	14.63	14.83	34.50	31.33	31.82	31.00	28.67	24.67	3093	2652	2596
L-19	4.57	4.53	4.62	13.28	13.95	14.18	33.82	33.93	36.17	32.83	34.17	36.83	3345	3024	2877
L-20	4.43	4.35	4.18	13.35	14.00	15.17	33.53	36.33	33.75	27.50	32.50	28.83	2897	3164	2754
SC.155		4.10			14.63			29.45			34.00			2950	
SC.3080		4.75			14.43			36.88			31.33			3410	
TWC.352		4.23			15.35			32.88			30.00			2937	
LSD 0.05		0.29			0.82			3.16			1.81			6.90	

gnificant positive SCA effects (favorable) for number of kernels per row. Seventeen crosses expressed significant positive SCA effects (favorable) for 100-kernel weight. However, the most desirable SCA effects for this trait were obtained by the top cross T1×L1 followed by T1×L12 and T1×L12. It could be concluded that the tester L-100 was the best among all testers for this trait since it exhibited the largest number of significant positive SCA effects. Regarding to grain yield, twenty-one crosses showed positive significant SCA effects (favorable). The best SCA effects were obtained from the two crosses T2xL12 and T1×L17. These two crosses significantly out-yielded the best check hybrid SC.3080 (3410 Kg/fad). Furthermore, the tester T2 (SC.101) exhibited the widest range between SCA effects for this trait. Therefore, it is recommended the immediate use of lines L4, L5, L10 and L12 as parents to develope three-way crosses with T2 (SC.101). Also, the immediate use of lines L7, L13 and L17 as parents in development of single crosses with T1 (L-100).

Superiority%

Data in Table 4 showed that the best hybrids for superiority over the check hybrid TWC. 352 were twenty topcrosses. However, most desirable superiority effects were detected for the top crosses T1 × L13, T1 × L17, T2 × L5, T2 × L10, T2 × L12 and T3 x L10. The useful superiority ranged from -17.12 to 30.62%. Whereas, nineteen topcrosses superiority over the check hybrid SC. 155 for grain yield. However, these crosses T1 × L7, T1 × L13, T1 × L17, T2 × L4, T2 × L5, T2 × L10 and T2 × L12 were the best among them. The useful superiority ranged from - 17.49 to 30.03%. Regarding to superiority over the check hybrid SC. 3080 only three topcrosses showed superiority for grain yield. However, the best useful superiority was obtained for the topcrosses T1 × L13, T1 × L17 and T2 × L12. Superiority over the check hybrid SC. 3080 ranged from -28.62 to 12.49%. Hence, it could be concluded that the previous top crosses offer possibility for improving grain yield in maize. Many investigators reported useful superiority for yield in maize (Ghonemy 2015, Ismail et. al. 2018 and Hassan et. al. 2016).

Conclusions

It is concluded that the parental line (L-19) possess high GCA effects for ear diameter, 100-kernel weight and grain yield while, the parental inbred line (L-13) possess high GCA effects for ear diameter, number of rows per ear and grain yield. The inbred line tester L-100 was the

Table 3 - Estimation of GCA in parents and SCA in the F1 progenies for all evaluated traits, diameter (ED), number of rows per ear (NRE), number of kernels per row (NKR), 100-Kernel weight (100KW) and grain yield per acre (GYPA).

Trait	ED (cm)				NRE				NKR				100KW (g)				GYPA (kg)			
Lines	GCA	SCA Combination			GCA	SCA Combination			GCA	SCA Combination			GCA	SCA Combination			GCA	SCA Combination		
		T1	T2	T3		T1	T2	T3		T1	T2	T3		T1	T2	T3		T1	T2	T3
L-1	0.14*	0.05	-0.09	0.04	0.24	-0.16	0.18	-0.01	0.26	0.02	0.65	-0.67	1.11**	3.47**	-1.08	-2.39**	2.23	2.13	-4.61	2.48
L-2	-0.07	-0.01	-0.05	0.06	-0.06	-0.01	-0.05	0.06	0.12	0.28	-0.26	-0.02	-2.45**	-0.31	1.48*	-1.17	-15.03 * *	-4.29	-5.10*	9.40**
L-3	0.13*	-0.03	-0.05	0.09	-1.19**	0.11	-0.74*	0.64*	1.12	-0.64	0.04	0.59	5.83**	-2.25**	0.20	2.06**	-4.52 * *	-1.68	5.04*	-3.36ss
L-4	-0.04	-0.15	0.14	0.01	0.40*	0.23	0.60*	-0.84**	1.21	-1.67	-0.06	1.74	-1.67**	-0.42	-0.64	1.06	4.92 * *	-14.71**	15.44**	-0.73
L-5	0.08	0.08	0.05	0.03	1.64**	-0.19	0.28	-0.08	-1.09	2.24*	0.77	-3.00**	-2.12**	-0.48	0.14	0.33	4.82 * *	-4.11	14.81**	-10.70**
L-6	0.09	-0.22*	0.07	0.15	0.89**	-1.11**	0.68*	0.44	-0.60	0.49	-1.40	0.91	-1.56**	-1.53*	-0.25	1.78**	0.48	-8.32**	-0.31	8.63**
L-7	-0.16**	0.18	0.02	-0.20	-0.45**	-0.05	-0.20	0.25	0.16	0.52	-0.55	0.03	-0.34	4.41**	-1.30*	-3.11**	0.18	17.42**	-11.18**	-6.24*
L-8	-0.09	0.09	-0.03	-0.07	-1.11**	0.26	-0.12	-0.14	0.17	1.06	-0.44	-0.63	0.94*	2.64**	-1.58*	-1.06	1.32	6.24*	-5.82*	-0.42
L-9	0.14*	-0.04	-0.09	0.13	-0.53**	-0.14	0.46	-0.33	-0.08	-1.29	-0.78	2.07	-1.17**	0.25	-0.30	0.06	-8.43 * *	-6.16*	-6.50**	12.65**
L-10	-0.15*	-0.09	0.13	-0.05	-0.79**	-0.70*	-0.11	0.80**	-0.88	0.51	0.86	-1.38	2.05**	-3.48**	0.81	2.67**	9.24 * *	-18.53**	12.88**	5.65*
L-11	-0.24**	0.02	-0.01	-0.01	-0.55**	-0.12	0.35	-0.24	2.45**	-0.55	1.69	-1.14	-4.12**	-1.81**	-0.19	2.00**	-1.87	-11.02**	1.09	9.94**
L-12	-0.06	-0.08	0.21*	-0.13	0.03	0.23	-0.56	0.33	3.01**	-1.36	0.78	0.58	1.33**	4.58**	-0.47	-4.11**	5.01 * *	-12.57**	28.11**	-15.54**
L-13	0.15*	0.07	0.00	-0.06	1.78**	0.87**	-0.09	-0.78**	-0.88	0.15	0.53	-0.68	0.72	-3.48**	0.47	3.00**	11.94 * *	18.87**	-9.84**	-9.04**
L-14	-0.09	-0.04	0.11	-0.07	-0.19	0.38	0.10	-0.48	-1.56*	0.29	-0.54	0.25	0.72	1.19	-0.02	-1.17	4.40 * *	2.93	2.52	-5.45*
L-15	0.05	0.02	0.00	-0.02	0.24	-0.01	-0.31	0.32	0.36	-3.24**	2.86*	0.38	1.88**	-2.48**	4.14**	-1.67*	-1.54	-4.67	-6.26*	10.93**
L-16	0.03	0.17	-0.06	-0.11	0.09	0.01	0.06	-0.06	-3.32**	2.88*	-4.59**	1.71	-0.17	1.75**	-1.14	-0.61	-7.06 * *	9.72**	-16.24**	6.51**
L-17	0.11	0.09	-0.21*	0.13	0.13	0.39	-0.46	0.07	-0.42	0.98	-0.84	-0.14	-0.45	1.86**	-3.19**	1.33*	1.56	19.26**	-25.00**	5.75*
L-18	0.09	0.05	-0.20	0.15	0.11	0.06	0.11	-0.18	-1.37*	1.69	-0.75	-0.94	-2.84**	1.91**	0.53	-2.44**	-7.18 * *	6.99**	1.31	-8.30**
L-19	0.20**	-0.05	0.00	0.05	-0.58**	0.03	0.11	-0.14	0.72	-1.09	-0.24	1.32	3.66**	-2.75**	-0.47	3.22**	2.95 *	7.41**	-0.71	-6.70**
L-20	-0.05	0.07	0.06	-0.13	-0.11	-0.07	-0.30	0.37	0.62	-1.27	2.26*	-0.99	-1.34**	-3.09**	2.86**	0.22	-3.41 *	-4.92*	10.37**	-5.46*
SE gi	0.06				0.17				0.65				0.37				1.43			
SE gi-gj	0.08				0.24				0.93				0.53				2.03			
T-1	0.05*				-0.55**				0.26				0.98**				3.19 * *			
T-2	-0.04				0.03				-0.47				0.03				-0.97			
T-3	-0.01				0.52**				0.20				-1.00**				-2.22 * *			
SE gi	0.02				0.06				0.25				0.14				0.55			
SE gi-gj	0.03				0.09				0.36				0.20				0.78			
SE SCA			0.10				0.29				1.13				0.65				2.48	

* and ** indicate significant at 0.05 and 0.01 probability levels, respectively.

Table 4 - Superiority% for 60 F1 crosses over the three checks (SC.155, SC.3080 and TWC. 352) for grain yield per acre (GYPA).

Crosses	SC. 155			SC. 3080			TWC. 352		
	T-1	T-2	T-3	T-1	T-2	T-3	T-1	T-2	T-3
L-1	8.52**	-0.35	4.39	-6.12 *	-13.79 * *	-9.69 **	9.00**	0.10	4.86
L-2	-10.75**	-14.79 **	-4.01	-22.79 * *	-26.29 * *	-16.96 **	10.35**	-14.41 * *	-3.58
L-3	-0.08	2.01	-5.84 *	-13.56 * *	-11.75 * *	-18.55 **	0.37	2.47	-5.42
L-4	-3.00	18.14**	3.97	-16.08 * *	2.21	-10.05 **	-2.56	18.67 * *	4.44
L-5	5.55	17.56**	-4.22	-8.69 * *	1.70	-17.14 **	6.02*	18.09 **	-3.79
L-6	-1.41	1.72	7.97 **	-14.71 * *	-12.00 * *	-6.59 **	-0.97	2.18	8.46 **
L-7	19.28**	-7.36*	-4.37	3.19	-19.86 * *	-17.27 **	19.82**	-6.95″	-3.94
L-8	11.12**	-2.07	1.30	-3.87	-15.28 * *	-12.36 **	11.62**	-1.63	1.76
L-9	-6.90*	-10.56**	4.00	-19.46 * *	-22.63 * *	-10.03 **	-6.48*	-10.16**	4.47
L-10	-2.59	19.58**	12.68**	-15.73 * *	3.45	-2.52	-2.15	20.12**	13.18**
L-11	-5.52	0.95	7.13*	-18.26 * *	-12.67 * *	-7.32 **	-5.09	1.40	7.61**
L-12	-1.18	28.53**	-8.00**	-14.51 * *	11.19 * *	-20.41 **	-0.74	29.11**	-7.59 **
L-13	30.03 **	3.29	2.93	12.49**	-10.64 * *	-10.96 **	30.62 **	3.76	3.39
L-14	10.93 **	7.21*	-0.28	-4.04	-7.25 * *	-13.74 **	11.43 **	7.70**	0.16
L-15	-0.08	-4.76	8.20 **	-13.56**	-17.61 * *	-6.39 **	0.37	-4.33	8.69**
L-16	7.13 *	-17.37 **	0.12	-7.32**	-28.52 * *	-13.38 **	7.61**	-17.00 **	0.57
L-17	21.90**	-17.49 **	6.51 *	5.45*	-28.62 * *	-7.86 **	22.45**	-17.12 **	6.99 *
L-18	4.81	-3.19	-12.03**	-9.33**	-16.25 **	-23.89 **	5.28	-2.75	-11.63 * *
L-19	13.40 **	3.40	-2.48	-1.90	-10.55 * *	-15.64 **	13.91**	3.87	-2.04
L-20	-1.80	7.25*	-6.64 *	-15.05 * *	-7.21 * *	-19.24 **	-1.36	7.74**	-6.22 *

* and ** indicate significant at 0.05 and 0.01 probability levels, respectively.

best combiner among the testers and expressed the best SCA effect over all crosses. Inbred line or single cross tester is preferred as it may permit quicker utilization of new lines in commercial hybrids especially if the tester is already in commercial use.

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