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NUMBER OF TESTERS SUITABLE FOR ESTIMATION COMBINING ABILITY OF YELLOW MAIZE INBRED LINES

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ABSTRACT

Information about combining ability is important for working breeding strategies. The objective of this study was to determine number of testers to be used for achieving reliable combining ability effects of tested inbred lines. Twenty three yellow maize inbred lines were crossed with four tester lines in a line x tester mating design in 2018 season. The 92 crosses and the check hybrid SC 168 were evaluated at two locations (Sakha and Sids Agricultural Research Stations) in 2019 season. The results indicated that more than one tester might be ideal for screening a large number of inbred lines. The best inbred lines for general combining ability effects were L8 followed by L6 and L13. The best hybrids for grain yield were L6 x Sk4, L8 x Sk4 and L8 x Sk2, in a descending order.

Key words: ***Line x tester, Mating design, Rank correlation.***

INTRODUCTION

The concept of general combining ability (GCA) and specific combining ability (SCA) has great importance for plant breeders. They are important indicators of potential value for inbred lines in hybrid combinations. The line x tester design has been used widely for preliminary evaluation of the combining ability of new inbred lines (Jenkins 1978, Hallauer and Miranda 1988, Barata and Carena 2006 and Fan *et al* 2008). But, there is no general agreement as to the best number and type of testers for this purpose. Mentono (1989) stated that an efficient tester is a tester that is capable of showing a greater range of variability of hybrids performances. Such tester would give most precise and accurate classification among entries for a given amount of testing. In the context, Gutierrez-Gaitan *et al* (1986), Vasal *et al* (1992) and Li *et al* (2007) emphasized the importance of testers, therefore the success of a maize breeding program depends on the choice of the most appropriate testers to select superior lines with a significant reduction of cost and labor. Hallauer and Carena (2009) stated that the testers should be the best elite lines of the breeding program one of dent and another of flint heterotic groups. These authors concluded that choice of best testers should be based on simplicity of its use, ability to classify the value of line, maximize genetic gain and enhance the expected mean yield of a population generated using selected cultivars. However, it is difficult to identify testers having such characters. Grogan and Zuber (1957) revealed that even one suitable tester may be sufficient for measuring GCA effects for grain yield, meanwhile Akhter *et al* (1985) concluded that two testers combination seems to be the optimal number compared with three testers combination. Abel and Pollak (1991) suggested at least two divergent testers that contain an inherently high level of favorable alleles. Li *et al* (2007) and Chandel *et al* (2014) found that one inbred tester can select the top best lines from a large number of inbred lines and two testers gave more reliable results than one tester did. Fan *et al* (2016) showed that three testers were economically best for testing GCA effects of lines and to obtain reliable SCA estimates.

Therefore, this study was undertaken with the following objectives: (1) to determine the best number of testers should be used to obtain reliable combining ability estimates of tested inbred lines. (2) To identify the best hybrids compared to a commercial hybrid.

MATERIALS AND METHODS

The experimental materials used in the present investigation comprised of twenty three new yellow maize inbred lines selected depending on their performance in S_5 generation at Sakha Agricultural Research Station, Egypt. The selected lines were crossed with four inbred line testers, Sk 2, Sk 3, Sk 4 and Gz 639 in a line x tester mating design in 2018 season. The 92 F_1 hybrids along with the check SC 168 were evaluated in a randomized complete block design with four replications at two locations *i.e* Sakha and Sids Agricultural Research Stations in 2019 season. Plot size was one row with a row length of 6 m and the spacing maintained was 0.8 m between the rows and 0.25 m between hills. The recommended packages of agricultural practices were followed in proper time to raise a good crop. Data were recorded on grain yield ardab/feddan (ard/fed) (one ardab = 140 kg and one feddan = 4200 m^2) adjusted at 15.5% grain moisture. Before calculating the combined analysis test of homogeneity error mean squares between locations was done according to Snedecor and Cochran (1980). Line x tester analysis was calculated based on the method described by Kempthorne (1957).

RESULTS AND DISCUSSION

The combined analysis of variance for grain yield revealed high significant differences among locations (Loc) and hybrids (H). Also the Loc x H interaction was highly significant, indicating that the different hybrids reacted differently to different environments (Table 1).

Table 1. Combined analysis of variance for grain yield across two locations.

SOV	df	Mean squares
Locations (Loc)	**1**	**20111.10****
Rep/loc	**6**	**27.60**
Hybrids (H)	**92**	**108.70****
H x Loc	**92**	**50.80****
Error	**552**	**11.19**

**** significant at 0.01 level of probability.**

Mean performance of 92 hybrids and check for grain yield (Table 2), ranged from 20.68 to 36.72 ard/fed for L1 x Sk3 and L6 x Sk 4, respectively. Fourteen hybrids did not significantly out-yield the check SC 168 (33.54 ard/fed). The best from them were L6 x Sk4, L8 x Sk4, L8 x Sk2, L17 x Sk4, L15 x Sk4, L10 x Sk4 and L21 x Sk4, in a descending order.

Line x tester analysis of variance for grain yield (Table 3), showed highly significant mean squares due to lines (L), testers (T) and L x T interaction, indicating that the inbred lines behaved significantly different in their respective hybrids, so greater diversity was shown among the four testers for evaluating the inbred lines, while significant L x T interaction suggest that inbred line may perform differently in yield of crosses depending on type of testers used. The L x Loc, T x Loc and L x T x Loc interactions were highly significant, indicating that the different inbred lines, testers and their interaction reacted differently to environments. Similar results were found by Soengas *et al* (2003), Mosa (2004), Guimaraes *et al* (2012) and Fan *et al* (2016).

Table 2. Mean performance of 93 crosses for grain yield across two locations.

Inbred line	Grain yield (ard/fed)			
	Tester			
	SK 2	Sk 3	SK 4	Gz639
L1	31.27	20.68	33.12	31.70
L2	32.15	23.44	30.67	31.22
L3	31.46	22.77	30.91	31.10
L4	30.37	30.87	33.55	31.41
L5	33.20	29.68	31.02	31.85
L6	31.69	32.19	36.72	32.25
L7	28.79	25.84	31.90	28.59
L8	35.98	31.66	36.40	34.67
L9	29.29	21.46	34.51	32.88
L10	32.69	23.72	35.33	31.06
L11	30.32	30.11	31.22	31.18
L12	33.55	29.14	22.13	29.82
L13	33.18	29.82	34.85	32.30
L14	30.82	30.66	31.70	31.12
L15	30.83	28.87	35.39	31.45
L16	30.34	24.97	34.69	31.79
L17	33.22	23.41	35.41	33.30
L18	27.98	21.62	34.15	32.41
L19	32.35	25.26	32.61	33.18
L20	29.05	26.53	32.38	31.15
L21	29.29	22.89	35.25	30.29
L22	29.88	25.75	29.82	31.48
L23	27.96	21.76	33.16	34.74
Check SC 168	33.54			
LSD 0.05	3.27			
LSD 0.01	4.31			

Table 3. Line x tester analysis of variance for grain yield across two locations.

SOV	df	Mean Squares
Lines (L)	22	76.24**
Testers (T)	3	1601.85**
L x T	66	52.24**
L x Loc	22	61.26**
T x Loc	3	392.40**
L x T x Loc	66	31.13**
Error	546	10.99

**** significant at 0.01 level of probability.**

The best inbred lines for general combining ability (GCA) effects for grain yield were L6, L8, L13 and L15 (Table.4). Meanwhile, the best tester for GCA effects was Sk4 followed by Gz639 and Sk2 (Table 5).

Table 4. Estimates of general combining ability effects for 23 inbred lines for grain yield across two locations.

Inbred line	GCA effects
L1	-1.312*
L2	-1.136*
L3	-1.449*
L4	1.044
L5	0.933
L6	2.704**
L7	-1.726**
L8	4.170**
L9	-0.971
L10	0.195
L11	0.202
L12	-1.848**
L13	2.031**
L14	0.570
L15	1.129*
L16	-0.059
L17	0.831
L18	-1.467*
L19	0.344
L20	-0.728
L21	-1.078
L22	-1.275*
L23	-1.103
LSD g_i 0.05	1.100
0.01	1.500
LSD g_i- g_j 0.05	1.624
0.01	2.138

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

Table 5. Estimates of general combining ability effects for 4 testers for grain yield across two locations.

Tester	GCA effects
Sk2	**0.609***
Sk3	**-4.284****
Sk4	**2.402****
Gz639	**1.274****
LSD g_i 0.05	**0.479**
0.01	**0.630**
LSD g_i- g_j 0.05	**0.677**
0.01	**0.891**

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

Eleven crosses had desirable specific combining ability (SCA) effects. The best from them were L12 x Sk3 followed by L12 x Sk2, L23 x Gz639, L14 x Sk3, L11 x Sk3, L4 x Sk3 and L21 x Sk4 (Table 6).

Table 6. Estimates of specific combining ability effects for 92 crosses for grain yield across two locations.

Inbred line	Tester			
	SK 2	Sk 3	SK 4	Gz639
L1	1.467	-4.226**	1.522	1.236
L2	2.171	-1.645	-1.099	0.573
L3	1.792	-2.005	-0.553	0.766
L4	-1.789	3.608**	-0.399	-1.419
L5	1.154	2.528*	-2.822*	-0.861
L6	-2.134	3.261**	1.110	-2.237
L7	-0.599	1.346	0.719	-1.465
L8	0.690	1.268	-0.679	-1.279
L9	-0.855	-3.792**	2.567*	2.070
L10	1.376	-2.695*	2.231	-0.912
L11	-0.994	3.682**	-1.890	-0.798
L12	4.278**	4.765**	-8.931**	-0.111
L13	0.033	1.567	-0.091	-1.509
L14	-0.863	3.866**	-1.774	-1.229
L15	-1.417	1.523	1.349	-1.455
L16	-0.714	-1.197	1.841	0.071
L17	1.278	-3.642**	1.671	0.693
L18	-1.669	-3.133**	2.707*	2.096
L19	0.890	-1.305	-0.642	1.058
L20	-1.333	1.037	0.200	0.096
L21	-0.748	-2.255	3.418**	-0.415
L22	0.041	0.801	-1.815	0.974
L23	-2.055	-3.356**	1.352	4.059**
LSD S_{ij} 0.05	2.297			
0.01	3.023			
LSD S_{ij}-S_{kl} 0.05	3.248			
0.01	4.276			

*, ** significant at 0.05 and 0.01 levels of probability.

Top eleven lines in their crosses with testers selected by different testers and different combination of testers for grain yield across two locations are shown in Table 7. Fifteen crosses methods were defined and employed for compares on purposes i.e. four crosses methods with one tester for each of the four testers, six crosses methods with two testers selected from all possible combination of the four testers, four crosses methods with three testers selected from all combinations of four testers and one crosses method with all four testers. The results showed that inbred lines L6, L8 and L13 were selected by all 15 crosses methods, indicating that one inbred line tester had the same efficiency as two or more inbred line testers in selecting the top best lines or inbred line tester might be good enough to identify the top best lines from a large number of inbred lines.

Table 7. Top eleven lines in their crosses with testers selected by different testers and different combination of testers for grain yield across two locations.

Four testers and their combinations														
*T1	T2	T3	T4	T12	T13	T14	T23	T24	T34	T123	T124	T134	T234	T1234
L-8	L-6	L-6	L-23	L-8	L-8	L-8	L-6	L-8	L-8	L-8	L-8	L-8	L-8	L-8
L-12	L-8	L-8	L-8	L-6	L-17	L-17	L-8	L-6	L-6	L-6	L-6	L-17	L-6	L-6
L-17	L-4	L-17	L-17	L-13	L-6	L-19	L-13	L-4	L-17	L-13	L-13	L-6	L-13	L-13
L-5	L-14	L-15	L-19	L-5	L-13	L-13	L-4	L-13	L-23	L-15	L-5	L-13	L-4	L-15
L-13	L-11	L-10	L-9	L-12	L-10	L-5	L-15	L-14	L-9	L-4	L-4	L-10	L-15	L-4
L-10	L-13	L-21	L-18	L-14	L-15	L-6	L-14	L-5	L-13	L-5	L-14	L-19	L-14	L-5
L-19	L-5	L-13	L-13	L-4	L-16	L-10	L-11	L-11	L-15	L-14	L-12	L-15	L-5	L-17
L-2	L-12	L-16	L-6	L-11	L-19	L-2	L-5	L-15	L-18	L-17	L-11	L-16	L-11	L-14
L-6	L-15	L-9	L-5	L-15	L-21	L-12	L-16	L-12	L-16	L-10	L-15	L-9	L-17	L-19
L-3	L-20	L-18	L-16	L-19	L-1	L-1	L-10	L-19	L-10	L-11	L-19	L-1	L-16	L-11
L-1	L-7	L-4	L-1	L-17	L-5	L-23	L-20	L-20	L-19	L-19	L-17	L-5	L-19	L-10

***T1=tester SK2, T2=SK3, T3=SK4, T4=Gz639, T12=two testers of SK1 and SK2 similar combination for T13, T14, T1234.**

The best inbred lines in the top eleven crosses for different combination of testers for grain yield across two locations is shown in Table 8. The results showed that one of the four tester methods with one tester could correctly select all the best inbred lines; meanwhile three of the four methods with one tester selected four from five best lines. If two or more testers were used, they could correctly select all top best inbred lines by all methods, except by T34 method (four from five), indicating that one inbred line tester might be enough for effectively screening a large number of lines, meanwhile two inbred lines testers or more might be ideal for screening a large number of lines. Similar results were obtained by Holland and Goodman (1995) and Chandel *et al* (2014).

Table 8. The best inbred lines in top eleven crosses for different combination of testers for grain yield across two locations.

Inbred lines	**Testers and their combinations**														
	***T1**	**T2**	**T3**	**T4**	**T12**	**T13**	**T14**	**T23**	**T24**	**T34**	**T123**	**T124**	**T134**	**T234**	**T1234**
L5	**+P**	**P**	**-**	**P**	**P**	**P**	**P**	**P**	**P**	**-**	**P**	**P**	**P**	**P**	**P**
L6	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**
L8	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**
L13	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**
L15	**-**	**P**	**P**	**-**	**p**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**

***T1=tester SK2, T2=SK3, T3=SK4, T4=Gz639, T12=two testers of SK1 and SK2 similar combination for T13, T14, T1234**
+P = indicate to present line in top eleven crosses selected by testers and their combinations

The ranks of 23 inbred lines crossed with the four testers for grain yield across two locations (in Table 9), showed that ranks of grain yield for each tester was not consistent, suggested the advisability of using more than one tester. The best inbred lines for consistent with testers were L8 followed by L6.

Table 9. The ranks of 23 inbred lines crossed with the four testers for grain yield across two locations.

Inbred line	Tester			
	SK2	SK3	SK4	Gz639
L1	11	1	13	11
L2	8	16	21	15
L3	10	19	20	19
L4	14	3	11	14
L5	4	7	19	9
L6	9	1	1	8
L7	21	11	16	23
L8	1*	2	2	2
L9	18	22	9	5
L10	6	15	5	20
L11	16	5	18	16
L12	2	8	23	22
L13	5	6	7	7
L14	13	4	17	18
L15	12	9	4	13
L16	15	14	8	10
L17	3	17	3	3
L18	22	21	10	6
L19	7	13	14	4
L20	20	10	15	17
L21	19	18	6	21
L22	17	12	22	12
L23	23*	20	12	1

Rank 1* = the highest grain yield.   Rank 23* = the lowest grain yield.

The correlation coefficients of ranks of 23 inbred lines with four testers for grain yield across two locations (in Table 10), were not significant, except correlation of ranks of 23 inbred lines with tester L4 and tester Gz639; this result indicate that more than one tester might be ideal for screening a large number of inbred lines.

Table 10. Correlation coefficient of ranks of 23 inbred lines with four testers for grain yield across two locations.

Tester	SK2	SK3	SK4	Gz639
SK2	-			
SK3	0.38	-		
SK4	0.12	0.04	-	
Gz639	0.13	-0.09	0.43*	-

***significant at 0.05 level of probability.**

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عدد الكشافات المناسب لتقدير القدرة الائتلافية لسلالات صفراء من الذرة الشامية

حاتم الحمادى موسى ، إبراهيم عبد النبى إبراهيم الجزار ، محمد عرفة على حسن ، سعيد محمد أبو الحارس ، هانى عبدالعاطى درويش ، عماد اسماعيل محمود محمد

مركز البحوث الزراعية – معهد بحوث المحاصيل الحقلية – قسم بحوث الذرة الشامية

معرفة القدرة على الائتلاف تكون مهمه لعمل استراتيجيات للتربية. تهدف هذه الدراسة الى تحديد عدد الكشافات المناسبة التى تستخدم لتقدير القدرة على الائتلاف لسلالات من الذرة الشامية. تم التهجين بين ٢٣ سلالة صفراء من الذرة مع اربع كشافات بنظام التزاوج السلالة في الكشاف فى موسم ٢٠١٨. تم تقييم الـ٩٢ هجين الناتجة مع هجين فردى ١٦٨ للمقارنة لصفة المحصول فى محطتى البحوث الزراعية بسخا وسدس فى موسم ٢٠١٩. اظهرت النتائج ان استخدام اكثر من كشاف يكون الافضل لإجراء الانتخاب لعدد كبير من السلالات. افضل السلالات فى تاثيرات القدرة العامة على الائتلاف هى سلاله ٨ يليها سلالة ٦ وسلالة ١٣. كان افضل الهجن فى محصول الحبوب: الهجين (سلالة ٦ × سلالة سخا ٤) ويليه الهجين (سلالة ٨ × سخا ٤) ثم الهجين (سلالة ٨× سلالة سخا٢).

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