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EVALUATING SOME NEW RESTORER LINES FOR COMBINING ABILITY USING EARLY TEST IN GRAIN SORGHUM

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ABSTRACT

Eighteen grain sorghum hybrids were developed from three elite cytoplasmic male sterile (A) lines ICSA 1, ICSA 37 AND ATX 631 and five F_4 restorer (R-lines) families resulting from crosses among some local cultivars and population (pop-1) used as restorer lines (R-lines) viz., Gzr1, Gzr2, Gzr3, Gzr4 and Gzr5, as well as the check variety Dorado at ARC, Giza during 2002 growing season. The hybrids and their parental lines were evaluated in field trials grown at three locations viz., Nubaria, Sids and Shandaweel Agric. Res. Stations during 2003 season.

Results of combined analysis generally displayed significant differences among A-lines, R-lines and their hybrids for all studied traits. Effects of females x males' interactions were insignificant except for plant height. The major role of additive genetic effects controlling grain yield and its components were proved. Grain yield showed a high estimate of 10.3% heterosis over the better parent in the cross ATX 631 x Gzr1.In general the three crosses ICSA-1 x Gzr4, ICSA-37 x Gzr3 and ATX 631 x Gzr4 gave the highest heterosis estimates for grain yield and most of the studied traits.

Three of the R-lines (Gzr1, Gzr3 and Gzr4) surpassed the check variety Dorado in general combining ability for grain yield. The superior crosses were ICSA-37 x Gzr3 and ATX 631 x Gzr3, which had significantly higher yield potentiality than the crosses involving the combiner check Dorado.

Key words: ***Sorghum, Heterosis, Cytoplasmic male sterility, Restorer lines, GCA, SCA***

INTRODUCTION

Two major aspects of breeding programs, generating genetic diversity and exploiting this diversity by selection usually are applied. Several exotic x local crosses are yearly done in the Egyptian sorghum improvement program to diversify the genetic base. Visual performance of segregate plants is the main criterion in the early generations. Thus large numbers of combined genotypes manipulate and maintain to reach genetic homozygosity under lax selection that causes expensive cost. On the other hand, strong selection may lead to loss of many genotypes of high combining ability.

Early testing of maize lines was suggested by Jenkins (1935), and has been a principal step in hybrid breeding programs. Andrews *et al* (1997) stated that selection or combining ability of sorghum parents of hybrids can begin at an early stage within F_3 families or even among F_2 plants in restorer lines (R lines) development. Therefore, it is possible to begin combining ability tests of candidate restorer lines in the breeding program, using the elite CMS lines (A-lines) as testers at early stages that would help detecting the good combiner restorers and might permit the heavy discarding of inferior lines and decrease the number handled. Crosses among parents of high general combining ability for most desirable traits would result in better hybrids for grain yield (Patel *et al* 1990). Identifying limited number of lines having high general combining ability in hybrid breeding program increases the chance of finding out hybrids of high yielding potential that utilize specific combining ability as well.

In the course of the present investigation, the combining ability of five restorer F_4 families used as restorers with three elite CMS lines, commonly used for sorghum hybrids production in Egypt, will be estimated compared with Dorado, the current restorer parent of most commercial hybrids.

MATERIALS AND METHODS

Three elite cytoplasmic male sterile lines (A-lines) ICSA-1, ICSA-37 and ATX631 were used as tester lines and were pollinated by pollen grains collected from five F_4 families resulting from crosses among some local cultivars and a population designated Pop-1. These crosses were (pop-1-1 x G113), (Sel2 x Sel 1007), (Pop-1-2 x G15), (Pop-1 x G113) and (ICSV 112 x L129) as well as the variety Dorado which is traditionally used as a restorer line. These families are designated as Gzr1, Gzr2, Gzr3, Gzr4 and Gzr5, respectively. The 18 hybrids were made at ARC, Giza during 2002 growing season. Hybrids and their parental lines were evaluated in field trials grown at three locations i.e. Nubaria, Sids and Shandaweel Agric. Res. Stations during 2003 season.

A randomized complete block design (RCBD) with four replications was used at each location. Plots were single ridges, 4 meter long spaced 0.6 m apart. Sowing was carried out in hills 20 cm apart along the ridges. Hills were thinned to 2 plants per hill. Recommended agricultural practices were done at the proper time and plant protection practices were applied as needed. Data were recorded on heading date, plant height (cm), 1000-kernel weight and grain yield (ard/fed). The genetic analysis was conducted by using line x tester analysis according to Kempthorne (1957). General (GCA) and specific (SCA) combining ability effects were estimated according to Singh and Chaudhary (1977).

Estimates of better parent heterosis (heterobeltiosis) were determined by using the following equation (F1-BP) x 100/ BP where F_1 = mean of the F_1 and BP mean of the better parent. Significance of the difference between the better parent and the F_1 was used as indication of significance for heterobeltiosis.

RESULTS AND DISCUSSION

Average performance

The initial screening of parental lines derived from early generation is necessary Andrews *et al* (1997). Data presented in Table (1) showed average performance over three locations of 18 sorghum hybrids and their parents for days to 50% heading, plant height, 1000 kernel weight and grain yield (Ard/Fed). These combined data were statistically analyzed.

The male sterile A-line (ICSA1) was the earliest genotype as it exerted panicles after 70.6 days from sowing and had the highest grain yield (17.4 ard/fed.) while the line ATX 631 had the highest 1000-kernel weight (25.2 g). The line ICSA-37 had the tallest plants (125.6 cm).

On the other hand, all tested restorer families were earlier, taller and had higher 1000-kernel weight and grain yield than the check pollinator Dorado. Days to 50 % heading for crosses ranged from 67.1 days (ICSA-1 x Gzr2) to 72.8 days (ICSA 37 x Gzr5).

The crosses (ICSA-37 x Gzr5), (ICSA-1 x Gzr1) and (ATX631 x Gzr1) were the tallest hybrids (284.6, 280.0 and 277.1 cm, respectively). In general, crosses were taller than the parental lines indicating hybrid vigor for plant height. Also, crosses involving the new restorers were showed taller than those involving the Dorado restorer.

1000-kernel weight for crosses ranged from 31.2 g (ICSA-37 x Gzr5) to 37.7 g (ATX631 x Gzr1). Most of the crosses had high 1000-kernel weight. The two hybrids (ATX 631 x Gzr1) and (ATX 631 x Dorado) had the highest 1000-kernel weight 37.7 and 37.4 g, respectively. The crosses involving Dorado did not show significant differences for 1000-kernel weight.

Table 1. Mean performance of 18 hybrids and their parents for days to 50 % heading, plant height, 1000-kernel weight and grain yield over three locations, 2003 season.

Genotypes	Days to 50 % heading	Plant height (cm)	1000-kernel weight , g	Grain yield ard/fed
ICSA-1 x Gzr-1	68.1	280.0	35.2	29.0
x Gzr -2	67.1	252.9	34.4	21.9
x Gzr-3	71.1	246.7	35.9	28.2
x Gzr-4	68.9	203.	35.1	28.1
x Gzr-5	69.2	267.1	33.2	27.1
x Dorado	71.9	159.2	34.4	25.2
ICSA-37 x Gzr -1	69.6	273.3	34.8	28.0
x Gzr-2	70.3	270.0	35.1	22.3
x Gzr-3	70.5	210.4	34.2	29.3
x Gzr-4	69.3	202.5	32.8	27.5
x Gzr-5	72.8	284.6	31.2	28.5
x Dorado	72.1	186.7	34.7	26.8
ATX631 x Gzr-1	67.4	277.1	37.7	29.9
x Gzr-2	67.3	263.3	35.1	25.4
x Gzr-3	70.7	222.5	36.1	29.5
x Gzr-4	69.4	223.3	36.5	29.0
x Gzr-5	69.1	268.3	34.9	23.5
x Dorado	72.0	197.1	37.4	24.9
Mean	69.2	238.1	34.9	26.3
Gzr-1	69.7	274.0	35.5	27.1
Gzr-2	68.3	258.9	33.8	27.8
Gzr-3	70.4	228.3	35.3	27.2
Gzr-4	70.3	207.3	32.7	26.8
Gzr-5	69.3	271.1	31.7	27.6
Dorado	72.8	184.8	30.6	26.7
ICSA-1	70.6	106.4	23.6	17.4
ICSA-37	73.4	125.6	23.1	11.0
ATX631	71.3	123.0	25.2	12.3
Mean	70.7	197.7	30.2	22.7
L.S.D 0.05	1.4	5.5	1.7	2.6

Regarding grain yield, the average yields of the crosses ranged from 21.9 ard/fed (ICSA-1 x Gzr2) to 29.9 ard/fed (ATX 631 x Gzr1). Three hybrids involving the tested families had lower grain yield than the hybrids involving Dorado. In general, most of the crosses had high grain yield compared with their parental lines. Finally, the higher grain yield of each of these crosses could be attributed to a high value of one or more of the yield components. The results revealed that the top four hybrids (ATX631 x Gzr-1), (ATX631 x Gzr-3), (ICSA37 x Gzr-3) and (ICSA 1 x Gzr1) produced 29.9, 29.5, 29.3 and 29.0 ard/fed, respectively. All their pollinator parents were new materials or from the tested families. However, the average productivity of the 18 hybrids was 26.3 ard/fed was significantly higher than the parental genotypes that produced 22.7 ard/fed. This result indicated the presence of significant average heterosis caused by genetic system controlling sorghum grain yield. These results are in agreement with those obtained by Reddy and Joshi (1993), Amir (1999), Mostafa and El-Menshawi (2001), El-Menshawi and El-Bakry (2004). They concluded that most of crosses were earlier, taller and had higher 1000-kernel weight and grain yield than their parents.

Heterobeltiosis

Estimates of useful heterosis shown by the F_1 hybrids as a percentage of the better parent averaged over locations for characters under study are presented in Table (2).

Table 2. Estimated heterosis as a percentage of the better parent of eighteen crosses over three locations, 2003 season.

Genotypes	Days to 50 % heading	Plant height (cm)	1000-kernel weight, g	Grain yield ard/fed
ICSA-1 x Gzr-1	-2.3**	2.2	-0.8	7.1**
x Gzr-2	-1.7*	-3.3	2.0**	-21.2**
x Gzr-3	1.0	8.1**	1.7	3.6*
x Gzr -4	-2.0*	-1.7	7.2**	5.0*
x Gzr-5	0.2	-1.5	4.7*	-2.2
x Dorado	1.9*	-13.0**	12.2**	-5.9*
ICSA-37 x Gzr-1	-0.12	-0.2	-1.9*	3.3*
x Gzr-2	3.1**	4.3	3.9*	-19.7**
x Gzr-3	0.1	-7.8**	-3.2*	7.8*
x Gzr-4	-1.4*	-2.3	0.1	2.8*
x Gzr-5	4.9**	4.3	-1.7*	3.0*
x Dorado	-1.0	1.0	13.2**	0.1
ATX631 x Gzr-1	-3.2**	1.1	6.2	10.3**
x Gzr-2	-1.5*	1.7	3.8*	-8.8**
x Gzr-3	0.4	-2.5	2.2*	8.5**
x Gzr-4	-1.3	7.7**	11.5**	8.3*
x Gzr-5	-0.4	-1.0	10.3**	-15.2**
x Dorado	1.1	6.7*	22.1**	-7.0*

*** and ** indicate significance at 0.05 and 0.01 levels, respectively.**

Negative heterosis for days to 50 % heading (earliness) is observed for 10 hybrids indicating that these hybrids were earlier than the earliest parent. The crosses involving Gzr1 had negative heterosis and two of them reached significant level, suggesting that this parent has genes showing heterosis toward earliness. In contrast, all crosses with Gzr3 displayed positive heterosis toward lateness while Dorado showed positive heterosis with two lines (ICSA-1 and ATX-631) and insignificant negative heterosis with ICSA-37. These results indicated that earliness or lateness of these crosses might be due to the genetic make up of the restorer parent.

For plant height, most of the hybrids had positive heterosis indicating these hybrids are taller than the tallest parent. The cross (ICSA-1 x Gzr3) and (ATX631 x Gzr4) were 8.1 % and 7.7 %, respectively, taller than its tall parent. On the other hand, two hybrids with Dorado showed positive heterosis for plant height but one hybrid (ICSA-1 x Dorado) 13.0 % was shorter than the tallest parent. In general, all hybrids showed variable negative and positive heterosis values with the same maternal lines.

For 1000-kernel weight, most of hybrids showed significant positive heterosis values. Also, heterosis was manifested in all crosses involving the new paternal materials (Gzr2) (Gzr4) and Dorado.

For grain yield, nine hybrids showed significant positive heterosis relative to their high parent. For crosses involving Gzr1, Gzr3 and Gzr4 as restorers, the highest positive significant heterosis was 10.3 %, observed by the hybrid (ATX631 x Gzr1). On the other hand, three hybrids showed significantly negative heterosis for grain yield indicating lower yield than the higher yielding parent, two hybrids involving Dorado were significantly negative indicating lower yield for these hybrids than the other hybrids. In general the crosses (ICSA-1 x Gzr4), (ICSA-37 x Gzr3) and (ATX631 x Gzr4) gave the highest heterosis values for grain yield (ard/fed) and all studied traits. These results are in harmony with those obtained by Sankara-Panadion *et al* (1994), Mahmoud (1997), Hovny *et al* (2001) and El-Menshawi and El-Bakry (2004). They reported that heterosis was manifested in grain sorghum crosses for many studied traits.

Analysis of variance

Mean squares for all studied traits of the combined analysis across three locations are presented in Table (3). The differences between locations were insignificant for all traits except 1000-kernel weight indicating that the three locations are similar in environmental conditions. Highly significant differences were detected among crosses, males, and females for all studied traits except grain yield and plant height for females and 1000 kernel weight for males. Insignificant interactions of females x males indicated the major role of additive genetic effects in controlling yield and yield components. Mean squares due to interaction of crosses, females and males with locations were insignificant except that of plant height, grain yield for crosses and males and plant height for females. The interaction with location indicates no difference in ranking of genotypes of females and males from one location to another; insignificant females x males interaction means squares were detected for all studied traits except plant height. These results indicated that additive genetic effect was the most important gene effects.

Table 3. Combined analysis of variance for grain yield ard/fed and other traits of 18 crosses over three locations, 2003 season.

S.O.V	df	Days to 50 % heading	Plant height (cm)	1000-kernel weight , g	Grain yield ard/fed
Location	2	155.0	1306.8	774.6**	75.2
Error (a)	6	38.2**	348.8	44.6*	148.9**
Genotypes (G)	26	35.5**	1238.1**	172.4**	281.1**
Crosses (C)	17	36.0**	1021.9**	29.5*	74.0**
C x P	1	53.4*	118503.3**	1628.6**	1285.0**
Parents (P)	8	32.1**	6611.3**	293.9**	595.7**
G x L	52	17.8*	11357.5**	25.2*	44.6
C x L	34	16.4	6673.7**	17.1	64.6*
C x P x L	2	132.1**	1426.5**	356.6**	23.9
P x L	16	6.6	15645.5**	1.1	4.6
Males effects	5	78.6**	10813.7**	35.1	188.4**
M x L	10	21.6	17178.8**	23.6	103.9**
Female effects	2	48.7*	446.0	114.6**	5.1
F x L	4	22.3	1379.8**	18.6	51.6
F x M	10	12.2	232.1**	9.7	30.7
F x M x L	20	12.7	1234.8**	13.5	47.5
Error (b)	156	11.8	184.0	17.1	41.0

Combining ability

General combining ability (GCA)

Estimates of GCA effects of the parental lines for the studied traits over three locations are presented in Table (4). For days to 50 % heading, the GCA effects for the new material (paternal lines) Gzr1, Gzr2 and Gzr4 as well as the two male sterile lines (maternal lines) ICSA-1 and ATX631 were negative and significant indicating that these lines had desirable gene action for earliness and are considered as good combiners for earliness. On the other hand, the ICSA-37 and Gzr3 and Dorado were positive and significant GCA indicating that they contribute genes for late heading.

Regarding the estimates of GCA effects for plant height the family Gzr1, Gzr2 and Gzr5 and female parent ICSA-1 showed positive significant effects indicating that these lines played an important role in increasing height while the local variety Gzr3, Gzr4 and Dorado had negative significant GCA effects. For 1000-kernel weight ATX631 had positive significant GCA effects, which would increase grain weight of hybrids while Gzr5 had negative significant effect on 1000-kernel weight.

Table 4: Estimates of general combining ability effects of three female and six male (sorghum parents) for days to 50 % heading, plant height, 1000-kernel weight and grain yield over three locations, 2003 season.

	Days to 50 % heading	Plant height (cm)	1000-kernel weight , g	Grain yield ard/fed.
Females				
ICSA-1	-0.44*	3.33*	0.22	-0.30
ICSA-37	0.95*	0.34	-1.13*	0.17
ATX631	-0.51*	-3.68*	1.35*	0.13
S.E. gi	0.41	1.60	0.49	0.75
Males				
Gzr-1	-1.45*	38.54**	1.10	2.08*
Gzr-2	-1.59*	23.81**	-0.08	-3.69*
Gzr-3	0.93*	-11.73**	0.48	2.13*
Gzr-4	-0.59*	-28.40**	-0.15	1.32*
Gzr-5	0.52	35.07**	-1.81*	-0.56
Dorado	2.18*	-57.29**	0.54	-1.28*
S.E. gi	0.57	2.26	0.69	1.06
S.E. (gi – gj)	0.81	3.14	0.97	1.51

With respect of grain yield as the final product of trait performance, the three restorer families Gzr1, Gzr3 and Gzr4 had significantly positive general combining ability indicating, that these families had favorable gene action and combine well for increasing grain yield than the check restorer Dorado. These results suggest that genotypes of high potential GCA can be identified early in the segregating generations of sorghum crosses.

The Gzr2 and Gzr5 families had significantly negative GCA effects for grain yield so that they can be safely discarded from the breeding program. These results are in harmony with those obtained by Jagadeshwar and Shinde (1992), Mostafa and El-Menshawi (2001) and El-Menshawi and El-Bakry (2004). They reported that general combining ability effects differed in magnitude among male and female parents for all studied traits.

Specific combining ability (SCA)

Estimates of SCA effects for all studied traits are presented in Table (5). Estimates showed only one cross (ICSA37 x Gzr3) that exhibited significant SCA estimate for heading date. This result indicated that earliness of this hybrid may be partly due to non-additive gene effects. Two crosses ICSA 37 x Gzr2 and ICSA 37 x Gzr5 showed significant positive SCA effects for lateness, probably due to the common parent ICSA 37.

Table 5. Estimates of specific combining ability effects of three females and six males (local variety) for days to 50 % heading, plant height, 1000-kernel weight and grain yield over three locations, 2003 season.

Genotypes	Days to 50 % heading	Plant height (cm)	1000-kernel weight , g	Grain yield ard/fed.
ICSA-1 x Gzr-1	0.16	6.53*	-0.49	0.36
x Gzr-2	-0.70	-5.83*	-0.18	-0.97
x Gzr-3	0.77	23.47**	0.73	-0.52
x Gzr-4	0.13	-2.78	0.53	1.03
x Gzr-5	-0.73	-2.92	0.30	-0.12
x Dorado	0.36	-18.47**	0.89	-1.16
ICSA-37 x Gzr-1	0.27	-3.13	0.05	-1.05
x Gzr-2	1.16*	8.26*	1.36	0.14
x Gzr-3	-1.20*	-15.76**	-0.05	-0.87
x Gzr-4	-0.83	-7.01*	-0.88	1.96*
x Gzr-5	1.47*	11.59*	-0.81	0.98
x Dorado	-0.87	6.04*	0.34	0.80
ATX631 x Gzr-1	-0.44	-3.40	0.44	-2.03*
x Gzr-2	-0.46	-2.43	-1.18*	0.38
x Gzr-3	0.43	-7.71*	-0.68	0.65
x Gzr-4	0.79	9.79*	0.36	3.00*
x Gzr-5	-0.74	-8.68*	0.51	0.86
x Dorado	-0.51	12.43**	0.55	1.84
S.E. effect	0.99	3.91	1.19	1.84

For plant height, five hybrids (ICSA-1 x Gzr1), (ICSA-1 x Gzr3), (ICSA 37 x Gzr2), (ICSA 37 x Gzr5) and (ATX 631 x Gzr4) involving one of the new restorers exhibited desirable SCA effects. These hybrids would have a higher green yield that was associated with plant height.

Regarding 1000-kernel weight, the SCA estimates showed that the significant positive SCA effect (1.36) was obtained from the hybrid (ICSA37 x Gzr2), while other hybrids had either significant negative or non-significant SCA effects. With respect to grain yield, SCA (1.96 and 3.00) were significant and positive for hybrids (ICSA-37 x Gzr4) and (ATX631 x Gzr4), respectively. These crosses manifested significantly higher grain yield than the check hybrids.

Finally, these results indicated the superiority of new pollinator families Gzr1, Gzr3 and Gzr4 in GCA effects for grain yield that could be attributed mainly to their superiority in GCA for 1000-kernel weight. These results also showed that the role of additive genetic effects was appreciably larger than dominance effects for most studied traits.

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الاختبار المبكر للقدرة علي الإئتلاف لبعض السلالات المعيدة للخصوبة في الذرة الرفيعة

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أجريت هذه الدراسة لتقدير القدرة العامة والخاصة علي التآلف وقوة الهجين لـ ١٨ هجين من الذرة الرفيعة للحبوب، تم إنتاجهم في محطة بحوث الجيزة موسم ٢٠٠٢، وذلك بالتهجين بين ثلاثة سلالات عقيمة، عقما ذكريا سيتوبلازميا، ICSA-1, ICSA- 37 وATX 631 وخمسة عائلات جيل الرابع (F_4) و معيدة للخصوبة هي Gzr2, Gzr3, Gzr4, Gzr5 و Gzr1 بالإضافة إلي صنف دورادو للمقارنة علي أساس قدرة التآلف .

تم تقييم الهجن وإبائهم في ثلاثة موقع (النوبارية، سدس و شندويل) موسم ٢٠٠٣. وحللت النتائج للحصول علي القياسات الوراثية، وقد أوضحت نتائج التحليل المشترك وجود فروق معنوية بين السلالات في معظم الصفات، وأظهرت النتائج ان التباين الوراثي المضيف أكثر أهمية في وراثة الصفات المدروسة. اظهرت الهجن ICSA 1 x Gzr4, ATX 631 x Gzr4 و ICSA 37 x Gzr3 أعلي قوة هجين لصفة محصول الحبوب، كما أظهرت هذه الهجن تفوقا في معظم الصفات المدروسة.

أوضحت النتائج أن الآباء Gzr1, Gzr3 و Gzr4 المعيدة للخصوبة لها قدرة موجبة علي التآلف لصفة المحصول وتتفوق علي أب المقارنة دورادو في هذه الصفة، وأظهر هجينيين من الهجن المدروسة اعلي قدرة محصولية لصفة المحصول وهي ICSA 37 x Gzr3 و ATX 631x Gzr3 وأظهرت هذه الهجن تفوقا معنويا علي الهجن التي شارك فيها الأب دورادو المعيد للخصوبة المستخدم للمقارنة.