POTENTIAL SEED YIELD OF STERILE F1 AND 3-WAY CROSSES ON FORAGE SORGHUM-SUDAN HYBRID IN EGYPT

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ABSTRACT

Male-sterile F1's from A x B line crosses and inbred A-lines of sorghum (*Sorghum bicolar* (L.) Moench) were investigated in relation to commercial production of hybrid seeds. Eight cytoplasmic male-sterile (CMS) A-lines, maintainer B-lines and the fertility restoring (R) sudangrass cultivar Greenleaf were selected to produce the hybrids evaluated in this study. Estimates of the parameters that describe seed yield and its components indicated that there were no general advantages for using sterile single crosses (SSC) over their prenatal (A) lines as the seed parent. As a group, the three-way hybrids and sterile single cross two way hybrids were not significantly different for any trait. However, some particular crosses showed significant positive heterosis for seed yield and its components, suggesting that dominant and epistatic gene actions were the cause of their superior performance. Therefore, the extra expense encountered in producing seed of a three-way sorghum-sudangrass hybrid could be compensated for by using the superior crosses identified in this study.

KEYWORDS

Sorghum - sudangrass hybrid, male-sterile F1, 3-way crosses, inbred lines, cytoplasmic male-sterility, maintainer, fertility restoring, Greenleaf

INTRODUCTION

Forage sorghum and maize play an important role in summer forage production in Egypt. The short supply of green fodder during the summer has always been critical for livestock production. Consequently, efforts have been directed towards improving the productivity of summer fodder crops especially sorghum-sudangrass hybrids. Such hybrids are better adapted and produce more quality fodder than fodder maize. In addition, seed production from sorghum-sudangrass hybrids is much easier than sudangrass. Single-cross sorghum-sudangrass hybrid seed is produced on cytoplasmic male-sterile lines of grain sorghum, therefore seed yield is low and seed cost is accordingly high. Any improvement in seed production would help reduce the cost of hybrid seed. Patanotahi and Atkins (1974) reported that seed costs from 3-way hybrids of grain sorghum will be lower than that of the single cross hybrid only if the yield superiority is large enough to offset the extra expense encountered in producing seed of the three-way hybrid. Previous research showed that seed produced with three way hybrids out-yielded a sterile cross hybrid and set more seeds per head (Stephens and Lahr, 1959; Walsh and Atkins, 1973). Other studies pointed out that increased seed set on F1's could be due to more florets per head, longer period of blooming, more heads per plant and higher threshing percentage, They concluded that F1 seed parents could be harvested earlier and allowed reduced grain drying costs. Several workers have presented evidence from experiments with grain sorghum which supports the contention that 3-way hybrid crosses may be more stable in performance than single crosses under variable environmental conditions (Hookstra and Ross 1982). The larger genetic diversity of 3-way hybrids should also provide on additional means of decreasing vulnerability of sorghum to diseases and insects (Jowett, 1972; Perez and Miller, 1980; and Khan, 1992). The objectives of this study were to: 1) compare seed yield and other agronomic traits between the male-sterile F1 seed parent (A x B) and their component A-line seed parents, 2) relate the findings to commercial forage hybrid seed production.

MATERIAL AND METHODS

The parents to produce the hybrids for this study were eight cytoplasmic male-sterile A-lines of grain sorghum and their maintainer B-lines, and the sudangrass cultivar Greenleaf was used as the fertility-restoring (R) pollen parents. The cytoplasmic male sterile lines as the following:

Number	Line		Origin	Designation
1	New Mexico	10459	U.S.A.	A1 , B1
2	Texas	622	U.S.A.	A2 , B2
3	Texas	622	U.S.A.	A3 , B3
4	Texas	624	U.S.A.	A4 , B4
5	New Mexico	10262	U.S.A.	A5 , B5
6	New Mexico	103660	U.S.A.	A6 , B6
7	Atlas	16	U.S.A.	A7 , B7
8	New Mexico	7021	U.S.A.	A8 , B8

In 1992, each A-line was crossed with each B-line to produce seed of 56 male-sterile single crosses in a breeding nursery at the Giza Experimental Station, ARC. However, only 45 crosses were produced due to the poor matching of flowering date between the parents. Reciprocals, such as A1 x B2 and A2 x B1 were not considered to be equivalent due to their cytoplasmic differences. In 1993, forty-five male-sterile single crosses (A x B) (F1 seed parents) and their male sterile parent A-lines were planted on a clay soil at Giza. From 1 to 5 rows represented one replication in a completely randomized design. The replicates were planted in single rows 3.50 m long and 0.60 m apart. All rows were overseeded and thinned to 20cm between plants.Three rows of the pollen source, the sudangrass cultivar Greenleaf (Gl) were planted for each 12 female seed parent row to produce single (A x Gl) and three-way (A x B) x Gl crosses. At heading, heads of the F1 seed parent plants (A x B) were paper bagged before anthesis and shaded pollen was stain-tested for viability. Nine hybrids produced stainable pollen; therefore, their heads were kept bagged. At maturity, the seeds were harvested from the (A x B) seed parents and the sterile A-lines. Data on 7 traits was taken by generally accepted field and laboratory procedures from the female seed parents. Number of heads per plant was calculated from the number of seed-bearing heads harvested. Also, head length on the main stalk was determined. Seed weight per head was determined from threshed dried heads. Seed weight was the average weight of three 100-seed samples harvested from each seed parent. Threshing percentage was measured as the percentage of grain weight to unthreshed head weight. Seed yield was the threshold weight from five plants. Plant height was determined from the soil surface to the upper leaves and to the top of the main stalk head at maturity. The statistical procedure used was a regular analysis of variance (Steel and Torrie 1980). Percentage heterosis for high parent (Laosuwan and Atkins, 1977) was calculated by using the following equation: High parent heterosis

$$(\%) = (F1 - HP) \times 100 / HP$$

where F1 and HP are the means for the F1 and higher parent values, respectively. High parent heterosis value were determined for the single and three-way hybrids for all the traits measured.

RESULTS AND DISCUSSION

1. Parents vs. hybrids. The CMS parent lines showed highly significant differences in plant height, number of heads/plant and head length (Table 1). However these differences were not reflected in significant seed yield differences among parent lines. On the other hand the SSC were highly significantly different in seed yield (Table 1). Also, they were significantly variable in flowering date, plant height, number of heads, head length, threshing percentage, seeds per head and 100-seed weight. As a group, however, the SSC were not significantly different from the mean of their parent in any trait. These results show no general advantage for using SSC over their parental A-lines as seed parents for hybrid seed production. This is generally not in line with earlier reports, which indicated advantages for SSC (Walsh and Atkins, 1973; Patanothai and Atkins, 1974; and Hookstra and Ross, 1982). Lack of superior yield for the SSC over the A-parents in the present study could be due to poor seed set on the SSC hybrids as a result of pollen insufficiency. This is assumed from the observation that seed yield was relatively low for the trial. It could also be the result of less genetic diversity among the group of CMS lines used.

2. Heterosis of individual sterile single crosses. Comparisons between SSC and their CMS parents indicated that 10 out of 45 SSC showed heterosis for plant height. Heterosis for plant height ranged between 11.8 and 25% with an average of 18.47% (Table 2). In the same respect, three SSC observed positive significant heterotic responses for number of heads/plant ranging from 56.7 to 83.3% with a mean of 58.89%. For head length, 13% SSC were superior to their parents with a mean heterosis of 18.5% and a range of 12.5 to 28.8% (Table 2). In addition, five SSC showed substantial heterosis for threshing percentage ranging from 196.8 to 228.1% with a mean of 264.3%. Also, four SSC expressed considerable heterosis for number of seeds/head ranging from 155.9 to 286.4% with an average of 189.02%. For the weight of 100 seeds, 6 SSC observed positive significant heterosis above their parents with a mean heterosis of 52.9% and ranged between 62.4 to 247.7% with a mean of 141.41% (Table 2). The positive heterosis was not only varied among these traits, but also varied from set to set. The possible explanations of these results may be due to dominant and epistatic gene action, but seed yield is likely a quantitative trait controlled by multiple gene action. The estimate of heterosis recorded (Table 2) for seed yield and its components are generally large in comparison with estimates reported in the literature. The main reason for this upward bias is the use of (A) lines to represent the parents for comparison of hybrid performance instead of using the corresponding (B) lines.

3. Trait contribution to seed yield heterosis. It was desirable to examine the relation between heterosis for seed yield shown by the SSC and yield related traits from the data (Table 2). Two out of 8 crosses were not heterotic for any trait related to seed yield. The cross (A4 x B8) exhibited 62.4% heterosis for seed yield but was not heterotic for any yield related trait. Likewise, the cross (A6 x B7), which exceeded its CMS parent by 111.8% in seed yield, showed no heterosis for other traits. But the other crosses showed heterosis for one or more yield related traits. The cross (A8 x B2) showed 113.7% heterosis for seed yield, 155.9% for seeds/head and 22.5% for head length. The cross (A8 x B6) showed 130.6 heterosis in seed yield 24.5% in head length and 21.0% in plant height. Of a total number of 41 cases of heterosis for traits other than seed yield (Table 2), only 10 pertained to SSC showing heterosis for yield. The remainder of cases involved SSC showing heterosis for yield. The remainder of cases involved SSC showing heterosis for one or more traits other than seed yield. The above mentioned results show that the traits which seemed to be most related to seed yield are seeds/head and head length, as these traits, singly or together, accounted for the heterotic seed yield shown by 3 out of 8 SSC. In the same trend, other studies reported that seeds/head is the component exerting the greatest effect on total grain yield in sorghum (Kirby and Atkins, 1968; Walsh and Atkins, 1973). The present results also show that other traits could make significant contributions to the seed yield superiority of particular crosses. For example, threshing percentage was the heterotic yield of one cross and 100-seed weight for another. Head length was both responsible for the yield heterosis of one cross along with seeds/head; whereas number of heads did not appear to be related to seed yield heterosis.

CONCLUSION

The male-sterile F1 seed parents in this study, as a group, were not significantly different from their A-lines counterparts for any trait. However, some particular male-sterile F1 crosses showed significant positive heterotic responses for seed yield and its components. This suggested that dominant and epistatic gene actions were the cause of their superior performance. Production of male-sterile F1ís require little more effort than the maintenance of an A-line, and both can be done in the same isolated block. Therefore, the extra expenses encountered in producing seed of a three-way sorghum-sudangrass hybrid could be compensated for by using the superior cross identified in this study.

Table 1

Mean squares from ANOVA for traits showing significant differences of 45 A-xB- F1's and 8 A-lines used as hybrid sorghum female parents.

Trait	Parental group F1's	Parental group A-Lines	A-Lines vs. F1's
Seed yield	3631.06**	3079.94	569.02
Seed per head	89666.62**	55348.40	2792.84
Threshing (%)	534.17*	583.94	102.05
100-seed weight	0.303**	0.09	0.339
Head length	30.09**	42.86**	6.29
No. of heads/plant	2.49**	2.67**	2.21
Plant height	387.91**	379.95**	64.79
50% flowering	44.97*	44.57	44.83

*, * * Significant mean square at the 0.05 and 0.01 probability levels, respectively.

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Table 2

Mean performance for 7 traits from sorghum (AxB) F1' s and their parent A-lines and the heterosis of the F1's expressed as a percentage of the high parent.

Crosses P1 x P2	F1's	A-lines	Heterosis (%)	Crosses P1 x P2	F1's	A-lines	Heterosis (%)
	Seed yield, kg/fed.				**Head length, cm**		
A3 xA7	561.90	161.60	247.71**	A3 x B2	35.70	30.60	16.76**
A4 x B8	649.60	400.00	62.40 *	A3 x B4	35.70		16.67**
A6 x B1	462.40	217.60	112.50 *	A3 x B6	39.40		28.76**
A6 x B7	460.80		111.76 *	A3 x B7	36.00		17.65**
A7 x B5	454.40	220.80	105.80 *	A4 x B5	40.00	34.30	16.62**
A8 x B1	456.60	218.60	108.60 *	A4 x B6	38.70		12.83 *
A8 x B2	467.20		113.72**	A6 x B3	38.90		13.41 *
A8 x B6	504.00		130.56**	A6 x B4	38.60		12.54 *
	Number of heads/plant			A7 x B3	34.50	29.90	15.38 *
				A8 x B2	30.00	24.50	22.54 *
A1 x B3	4.70	3.00	56.67 **	A8 x B4	30.00		22.54**
A1 x B4	5.50		83.33 *	A8 x B5	31.20		27.35**
A1 x B5	5.00		66.67 *	A8 x B6	30.50		24.49**
	100-Seed weight, g				**Plant height, cm**		
A6 x B2	2.74	1.81	51.38 **	A1 x B2	131.00	115.40	13.52 *
A6 x B4	2.89		59.67 **	A1 x B3	135.70		17.59**
A6 x B8	2.94		62.43 **	A1 x B5	144.30		25.04
A7 x B4	3.00	2.20	36.36 *	A3 x B2	143.10	128.00	11.76 *
A7 x B5	2.91		32.27 *	A3 x B6	157.20		22.81**
A8 x B7	2.97	2.23	33.18 *	A4 x B6	142.70	125.50	13.71 *
				A8 x B2	124.50	105.20	18.25 *
				A8 x B4	129.00		22.62 *
				A8 x B5	125.80		19.58 *
	Threshing (%)			A8 x B6	127.30		21.01**
					Seed per head		
6 x B1	63.70	16.7	281.44 **				
A6 x B1	60.45		281.98 **	A3 x B7	833.39	215.71	286.35**
A6 x B4	65.67		293.23 **	A8 x B1	758.13	293.23	158.54 *
A6 x B5	49.56		196.77 **	A8 x B2	750.31		155.88 *
A6 x B8	64.82		288.14 **	A8 x B3	824.10		227.88 **

*, **Significant at the 0.05 and 0.01 propability levels, respectively.