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Inheritance of Fertility Restoration in *Sorghum* (Moench) *

by

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Introduction: The practical exploitation of hybrid vigour in *Sorghum* received considerable fillip with the discovery of cytoplasmic-genic male-sterile system in the Milo-Kafir crosses by Stephens and Holland (1954). Information on the fertility restoration in m. s. C. K. 60 by a range of *Sorghum* types and knowledge of the inheritance of fertility restoration in chosen combinations of crosses that would be useful in planning the future programme of work.

Material and Methods: I. S. 160–A, a cytoplasmic-genic male-sterile *Sorghum* line designated as male-sterile Combine Kafir–60, obtained from the Regional Research (Indian Council of Agricultural Research) Centre Coimbatore, along with its maintainer, the isogenic fertile counterpart, Combine Kafir–60, formed the basic material for the studies. Twenty two *Sorghum* types maintained at the Millet Breeding Station, Coimbatore, representing the different species of Snowden (1936) were used as pollen parents to hybridise with m. s. C. K. 60. The types are listed below.

S. No.	Species name (Snowden, 1936)		Type No
1.	*S. roxburghii* (Stapf)	...	A. S. 3880; Cp 19
2.	*S. nervosum* (Bess. exschult)	...	A. S. 1741
3.	*S. dochna* (Forsk)	...	K. 3; A. Ch. 121
4.	*S. nigricans* (Ruiz at Pavon)	...	A. S. 5823, A. S. 4649
5.	*S. caudatum* (Stapf)	...	A. S. 6199
6.	*S. durra* (Stapf)	...	Co. 1
7.	*S. cernuum* (Host)	...	A. S. 3488
8.	*S. splendidum* (Hact)	...	A. S. 210
9.	*S. subglabrescens* (Schweinf et Aschers)	...	Co. 18, K. 2 & A. S. 5037
10.	*S. guineense* (Stapf)	...	A. S. 4959
11.	*S. conspicuum* (Snowden)	...	A. S. 3960
12.	*S. sudenense* (Stapf)	...	A. S. 178, S. 194
13.	*S. virgatum* (Stapf)	...	S. 318
14.	*S. verticilliflorum* (Stapf)	...	S. 336, S. 276
15.	*S. arundinaceum* (Stapf)	...	S. 275

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Out of the 22 F_1 hybrids, the study of the F_2 populations and test-crosses with m. s. C. K. 60 was restricted only to those combinations involving the first eleven pollen parents enumerated above. The segregation for male-fertility was studied during 1962 monsoon season.

Three classes of pollen fertility based on stainability in 1 : 1 glycerine-acetocarmine were recognized *viz.*, 1. *Fully stainable* (F) (All pollen were filled and stainable) 2. *Partially stainable*: (P. F.) (Stainable and non-stainable pollen in different proportions.) and 3. Non-stainable (S): (All pollen without any content and not stainable). The selfed seed set was ascertained by covering the panicles two or three days before anthesis and estimating the seed set at maturity. Three arbitrary classes *viz.*, 'Full', 'Partial' and "Nil" seed set were made.

The inheritance of genes for male-fertility restoration was studied by observing the expression of male-fertility in the F_1 of different *Sorghum* types with m. s. C. K. 60, their F_2s and their test-crosses with m. s. C. K. 60.

Results: 1. *Study of F_1 F_2 & BC_1 F_1s for fertility restoration:* All the plants in twenty one F_1 hybrid combinations had normal looking anthers dehiscing and shedding considerable amount of pollen. The selfed panicles had good seed set. In the cross m. s. C. K. 60 x *S. subglabrescens* (A. S. 5037) alone the hybrid plants were partially sterile giving poor seed set when selfed. Eleven of the twenty two above mentioned hybrid combinations F_2s and test crosses with the male sterile parent, were studied for pollen fertility and selfed seed set, in 1962 monsoon season, and the results are presented in table 1.

The F_1s varied in the expression of male-fertility. In three of the F_1 populations all the plants were fully pollen-fertile while in four all the plants were partially pollen fertile. The rest of the F_1 populations showed segregation for male-fertility. Excepting two *Sorghum* types the rest had either fully or partly restored fertility to m. s. C. K. 60 resulting in either case a full seed set in the F_1 under bagged condition. In no F_1 all the plants were completely male-sterile though two combinations m. s. C. K. 60 x *S. nervosum* (A. S. 1741) and m. s. C. K. 60 x *S. nigricans* (A. S. 5823) had a proportion of completely male-sterile plants.

2. *Study of segregating generations:* The pattern of segregation in the different F_2 populations and test-crosses varied and did not fit in directly with any of the Mendelian ratios in such a way that the F_2 and the test cross data corroborated each other. However, three broad groups could be recognised as follows in the inheritance pattern.

TABLE 1. *Inheritance of male fertility restoration in m. s. C. K. 60*

The F_2 and test crosses	Pollen stainability				Selfed seed set			
	No. of plants				No. of plants			
	F	P. F.	S	Total	Full	Part	Nil	Total
1	2				3			
Group i.								
1. m. s. C. K. 60 x *S. roxburghii* (A. S. 3880) F_2 ...	80	11	15	106	76	5	20	101
2. m. s. C. K. 60 x (m. s. C. K. 60 x *S. roxburghii* – A. S. 3880) ...	24	4	14	42	26	4	11	41
3. m. s. C. K. 60 x *S. roxburghii* (Co. 19) F_2 ...	53	13	17	83	52	17	18	87
4. m. s. C. K. 60 x (m. s. C. K. 60 x *S. roxburghii* – Co. 19) ...	15	9	20	44	22	5	21	48
5. m. s. C. K. 60 x *S. cernuum* (A. S. 3488) F_2 ...	46	22	15	83	53	20	8	80
6. m. s. C. K. 60 x (m. s. C. K. 60 x *S. cernuum* – A. S. 3488) ...	19	10	17	46	17	6	15	38
7. m. s. C. K. 60 x *S. splendidum* (A. S. 210) F_2 ...	59	21	6	86	63	12	9	84
8. m. s. C. K. 60 x (m. s. C. K. 60 x *S. splendidum* – A. S. 210) ...	14	12	19	45	18	2	25	45
Group ii.								
1. m. s. C. K. 60 x *S. subglabrescens* (Co. 18) F_2 ...	22	59	11	92	46	20	15	81
2. m. s. C. K. 60 x (m. s. C. K. 60 x *S. subglabrescens* – Co. 18) ...	—	35	15	50	15	16	17	48
3. m. s. C. K. 60 x *S. durra* (Co. 1) F_2 ...	20	37	6	63	35	20	11	66
4. m. s. C. K. 60 x (m. s. C. K. 60 x *S. durra* – Co. 1) ...	—	25	15	40	18	11	21	50
5. m. s. C. K. 60 x *S. dochna* (K. 3) F_2 ...	37	52	4	93	88	6	3	97
6. m. s. C. K. 60 x (m. s. C. K. 60 x *S. dochna* – K. 3) ...	—	33	9	42	21	10	11	42
7. m. s. C. K. 60 x *S. dochna* (A. Ch. 121) F_2 ...	21	53	6	80	52	15	9	76
8. m. s. C. K. 60 x (m. s. C. K. 60 x *S. dochna* – A. Ch. 121) ...	—	26	16	42	12	11	18	41
9. m. s. C. K. 60 x *S. caudatum* (A. S. 6199) F_2 ...	69	52	19	134	121	11	11	143
Group iii.								
1. m. s. C. K. 60 x *S. nigricans* (A. S. 5823) F_2 ...	7	55	47	109	23	31	60	114
2. m. s. C. K. 60 x (m. s. C. K. 60 x *S. nigricans* – A. S. 5823) ...	—	17	33	50	1	9	39	49
3. m. s. C. K. 60 x *S. nervosum* (A. S. 1741) F_2 ...	10	48	32	90	22	26	32	80
4. m. s. C. K. 60 x (m. s. C. K. 60 x *S. nervosum* – A. S. 1741) ...	—	22	31	53	—	19	34	53

Group i: The proportion of completely pollen fertile plants in the crosses was high both in the F_2 and testcross and that of partially fertile plants was less (Table 1). 1. m. s. C. K. 60 x *S. roxburghii* (A. S. 3880) 2. m. s. C. K. 60 x *S. roxburghii* (Co. 19) 3. m. s. C. K. 60 x *S. cernuum* (A. S. 3488) 4. m. s. C. K. 60 x *S. splendidum* (A. S. 210). The proportion of completely pollen sterile plants ranged from 1/16 to 1/4 of the total number of plants in the F_2 and 1/4 to 1/2 in the testcross. The realization of large proportions of completely male-sterile segregates is suggestive that the genetic situation is basically simple with major gene control but subject to modifier influence. If fully pollen fertile and partially pollen fertile classes were clubbed the segregation in the F_2 and testcross of the hybrid m. s. C. K. 60 x *S. roxburghii* (Co. 19) and m. s. C. K. 60 x *S. cernuum* (A. S. 3488) fitted with monogenic, three combined class: one sterile and one combined class: one sterile, ratios respectively (Table 2).

The segregation observed in ten of the progenies of the second and third backcross lines with *S. roxburghii* (A. S. 3880) as recurrent parents is presented in Table 3. The observed ratio found a good fit with an expected 12 fertile: 3 partially fertile: 1 sterile ratio (Table 3), based on the assumption of a single dominant major gene and a partial restorer (a modifier) for fertility restoration. In the presence of the dominant major gene for full fertility restoration the presence of the partial restorer cannot be detected and hence the epistatic 12 : 3 : 1 ratio.

Group ii: The F_1 in these crosses consisted of partially pollen fertile plants giving full seed set when selfed (Table 1). 1. m. s. C. K. 60 x *S. subglabrescens* (Co. 18) 2. m. s. C. K. 60 x *S. durra* (Co. 1.) 3. m. s. C. K. 60 x *S. dochna* (K. 3) 4. m. s. C. K. 60 x *S. dochna* (A. Ch. 121) 5. m. s. C. K. 60 x *S. caudatum* (A. S. 6199). In the F_2, majority of the plants were partially pollen fertile but a considerable proportion of fully fertile plants also appeared. In the testcross no completely fertile plants were observed. The proportion of completely male-sterile plants ranged from 1/16 to 1/4 of the total number of plants in F_2 and 1/4 to 1/2 in the testcross. The partial fertility in the F_1 is suggestive of the absence of the dominant major gene for fertility restoration. The occurrence of a considerable proportion of fully pollen fertile segregates in the F_2 is indicative of the cumulative action of partial restorers leading to full fertility restoration. The relatively large proportions (1/16 to 1/4 in the F_2 and 1/4 to 1/2 in the testcross) of completely male-sterile individuals indicated that the number of genes determining the inheritance of fertility restoration in these combinations might not be more than two.

TABLE 2. *Inheritance of male fertility restoration in m. s. C. K. 60 (Fertile and partially fertile classes combined into one composite fertile class*

S. No.	The F_2s and test crosses		Pollen stainability: No. of plants: Combined class	Sterile	Total	Expected ratio	f^2 (chi²)	P between
1.	COMBINATIONS FALLING UNDER GROUP i.							
(a)	(i) m. s. C. K. 60 x *S. roxburghii* (Co. 19) F_2	...	65	17	83	3 : 1	0·904	0·30 — 0·50
	(ii) m. s. C. K. 60 x (m. s. C. K. 60 x *S. roxburghii* – Co. 19 test cross)	...	24	20	44	1 : 1	0·364	0·50 — 0·70
(b)	(i) m. s. C. K. 60 x *S. cernuum* (A. S. 3488) F_2	...	68	15	83	3 : 1	2·124	0·10 — 0·20
	(ii) m. s. C. K. 50 x (m. s. C, K. 60 x *S. cernuum* – A. S. 3438 test cross)	...	29	17	46	1 : 1	3·130	0·05 — 0·10
2.	COMBINATIONS FALLING UNDER GROUP ii.							
(a)	(i) m. s. C. K. 60 x *S. durra* (Co. 1) F_2	...	57	6	63	15 : 1	1·152	0·20 — 0·30
	(ii) m. s. C. K. 60 x (m. s. C. K. 60 x *S. durra* – Co. 1) test cross	...	25	15	40	3 : 1	3·233	0·05 — 0 10
(b)	(i) m. s, C. K. 60 x *S. dochna* (K. 3) F_2	...	89	4	93	15 : 1	0 602	0·30 — 0 50
	(ii) m. s. C. K. 60 x (m. s. C, K. 60 x *S. dochna* – K. 3) test cross	...	33	9	42	3 : 1	0·285	0·50 — 0·70
(c)	(i) m. s, C. K. 60 x *S. dochna* (A. Ch. 121) F_2	...	74	6	80	15 : 1	0·213	0 50 — 0·70
	(ii) m. s. C. K. 60 x (m, s. C. K. 60 x *S. dochna* A. Ch. 121) – test cross	...	26	16	42	3 : 1	3·841	0·50 —
(d)	(i) m. s. C. K. 60 x *S. caudatum* (A. S. 6199) F_2	...	121	13	134	15 : 1	1·724	0 05 — 0·10
3.	COMBINATION FALLING UNDER GROUP iii.							
	(i) m. s. C. K. 60 x *S. nigricans* (A. S. 5823) F_2	...	62	47	109	9 : 7	0·095	0·70 — 0 80
	(ii) m. s. C. K. 60 x (m, s. C. K. 60 *S. nigricans* – A. S. 5823) test cross	...	17	33	50	1 : 3	2·160	0·10 — 0·20

TABLE 3. *Inheritance of male-fertility restoration in m. s. C. K. 60 (Detailed analysis)*

The second generation of cross	Pollen stainability: No. of plants: F.	P. F.	S.	Total	Expected ratio	χ^2 (chi^2)	P between
1	2				3	4	5
1. COMBINATIONS FALLING UNDER GROUP ii.							
(i) m. s. C. K. 60 x *S. durra* (Co. 1) F_2 ...	20	37	6	63	5 : 10 : 1	1·229	0·50 — 0·70
(ii) m. s. C. K. 60 x *S. dochna* (K. 3) F_2 ...	37	52	4	93	5 : 10 : 1	3·384	0·10 — 0·20
(iii) m. s. C. K. 60 x *S. dochna* (A. Ch. 121) F_2 ...	21	53	6	80	5 : 10 : 1	1·020	0·50 — 0·70
(iv) m. s. C. K. 60 x *S. caudatum* (A. S. 6199) F_2 ...	69	52	13	134	9 : 6 : 1	3·154	0·20 — 0·30
2. COMBINATIONS FALLING UNDER GROUP iii.							
m. s. C. K. 60 x *S. nigricans* (A. S. 5823) F_2 ...	7	55	47	109	1 : 8 : 7	0·019	0·90 —
3. SELF BACK CROSS OF THE HYBRID m. s. C. K. 60 x *S. roxburghii* (A. S. 3880) WITH *S. roxburghii* (A. S. 3880).							
(i) Selfed second backcross line 20 ...	56	17	3	76	12 : 3 : 1	1·1888	0·20 — 0·30
(ii) ,, ,, line 21 ...	24	7	3	34		0·514	0·30 — 0·50
(iii) ,, ,, line 29 ...	41	6	3	50		1·537	0·20 — 0·30
(iv) Selfed third backcross line 27 ...	34	9	1	44		1·218	0·20 — 0·30
(v) ,, ,, line 34 ...	45	9	5	59		0·932	0·30 — 0·40
(vi) ,, ,, line 40 ...	34	5	2	41		1·407	0·20 — 0·30
(vii) ,, ,, line 62 ...	24	5	3	33		0·667	0·30 — 0·50
(viii) ,, ,, line 64 ...	9	3	1	13		0·246	0·50 — 0·70
(ix) ,, ,, line 65 ...	21	3	1	25		1·080	0·20 — 0·30
(x) ,, ,, line 72 ...	26	8	3	37		0·478	0·30 — 0·50
Total ...	314	72	26	411		0·458	0·30 — 0·50
4. SELFED 1ST AND 2ND BACKCROSS OF THE STERILE SEGREGATE FROM THE F_4 OF THE HYBRID m. s. C. K. 60 x *S. subglabrescens* (Co. 18) WITH *S. subglabrescens* (Co. 18)							
(i) Selfed first backcross line 2 ...	10	16	1	27	5 : 10 : 1	0·618	0·70 — 0·80
(ii) Selfed first backcross line 3 ...	15	26	2	43		0·348	0·80 — 0·90
(iii) Selfed second backcross line 11 ...	10	10	1	30		0·458	0·70 — 0·80
(iv) Selfed second backcross line 20 ...	4	11	1	16		0·300	0·80 — 0·90
Total ...	89	72	5	116		0·911	0·50 — 0·70

If the fully pollen fertile and partially pollen fertile classes were combined the segregation in the combinations m. s. C. K. 60 x *S. durra* (Co. 1), m. s. C. K. 60 x *S. dochna* (K. 3) and m. s. C. K. 60 x *S. dochna* (A. Ch. 121) fitted with digenic 15 combined class: 1 sterile and 3 combined class: 1 sterile ratios in the F_2 and testcross respectively (Table 2). The segregation in F_2 of the combination m. s. C. K. 60 x *S. caudatum* (A. S. 6199) also agreed with a 15 combined class: 1 sterile ratio (Table 3).

A further analysis of the F_2 segregation for pollen fertility in the hybrids m. s. C. K. 60 x *S. durra* (Co. 1)., m. s. C. K. 60 x *S. dochna* (K. 3) and m. s. C. K. 60 x *S. dochna* (A. Ch. 121) revealed that the actually observed ratios could be fitted with 5 fertile: 10 partially fertile: 1 sterile ratios, a modified form of 9 : 6; 1 ratio, if fertility restoration is not complete in the double heterozygote class (Table 3). The F_2 segregation is the combination m. s. C. K. 60 x *S. caudatum* (A. S. 6199) fitted well with a 9 : 6 : 1 ratio (Table 3).

The segregations observed in two of the selfed first backcross lines and in two lines (lines 11 and 20) of the selfed second backcross with m. s. C. K. 60 as non-recurrent and *S. subglabrescens* (Co. 18) as the recurrent parents, are presented in Table 3. A good fit of observed ratio with a 5 fertile: 10 partially fertile: 1 male-sterile ratio, a modified form of 9 : 6 : 1 ratio was obtained (Table 3).

Group iii: The remaining two hybrid combinations *viz.*, 1. m. s. C. K. 60 x *S. nigricans* (A. S. 5823) and 2. m. s. C. K. 60 x S. *nervosum* (A. S. 1741) (Table 1) appeared to differ from the rest in that there were a few completely male-sterile plants in the F_1 itself. The F_2 recorded a large proportion of male-sterile plants. The testcross consisted of a major proportion of male-sterile individuals. No fertile plants were observed in the testcross.

If the fully pollen fertile and partially pollen fertile classes were combined into one, the observed ratio in the combination m. s. C. K. 60 x *S. nigricans* (A. S. 5823) could be fitted with a 9 combined class: 7 sterile and 1 combined class: 3 sterile complementary rotios in the F_2 and testcross respectively (Table 2). The F_2 segregation for pollen fertility in this combination on closer observation could be fitted with a 1 fertile: 8 partially fertile: 7 male- sterile ratio a modified form of 9 : 7 ratio, where, only the homozygous double dominant class results in complete male-fertility (Table 3).

Discussion: 1. *Fertility restoration in m. s. C. K. 60 cytoplasm:* Most of the Indian *Sorghums* tested under the "Accelerated Hybrid *Sorghum* Project" (Indian council of Agricultural Research) at Coimbatore were found to restore male-fertility in their hybrids with m. s. C. K. 60. Joglekar and Deshmukh (1961) reported that all the local *Sorghum* types of the Vidharbha region contained restorers for male-sterile Kafir. Craigmiles (1962) found that fourteen out of fifteen varieties of Sudangrass tested restored male-fertility in their F_1 with m. s. C. K. 60. The average frequency of 'MSc' factor (restorer gene) for all the entries was found to be 0·61 by Maunder (1960).

Shambulingappa and Magoon (1963) reported that hybrids such as m. s. Kafir x *S. ankolib* and m. s. Kafir x *S. melaleucum* showed normal meiosis but 60 to 40 per cent of pollen sterility. However a good seed set was reported to have been recorded. In the present investigation a preliminary study of the nature of anthers and selfed seed set in the F_1s of m. s. C. K. 60 with pollen from 22 of different *Sorghum* species of *Snowden* (1963) suggested that all of them possessed genes for fertility restoration. A detailed study of eleven of the types revealed that four of them might not be homozygous for male-fertility restoration, as segregation for male-fertility was observed in the F_1 itself. In these cases, the parent lines might be heterozygous for the fertility restoring factors. This situation is possible due to the non-operation of any selection pressure for fertility restoration in the evolution of these *Sorghum* types. However, in none of the cross combinations studied all the F_1 plants proved to be completely male-sterile. This indicates that the genes for fertility restoration are widely distributed in the types of *Sorghum*, represented by the different species of Snowden (1936) used in the present study. The wide-occurrence of such fertility restoring genes in the range of *Sorghum* types handled, without any selection pressure for the same, is possibly due to a pre-adaptative mechanism for fertility, as in the case of characters like disease resistances referred to by Knight (1947). The availability of fertility restorers in most of the *Sorghum* types facilitates the direct use of hybrids with m. s. C. K. 60, for commercial exploitation.

1. *Inheritance of fertility restoration in m. s. C. K. 60:* GROUP i. DOMINANT MAJOR GENE CONTROL: Among the 11 hybrids tested in detail *Sorghum roxburghii* (A. S. 3880 and Co. 19) *S. cernuum* (A. S. 3448) and *S. splendidum* (A. S. 210) appeared to possess dominant complete fertility restorer. It was found that the inheritance of fertility restoration in *S. roxburghii* (Co. 19) and *S. cernuum* (A. S. 3488) was basically monogenic (Table 2). It was inferred that male-fertility in *S. roxburghii* (A. S. 3880) might be determined by one major gene for full restoration with epistatic effect and a minor gene for partial restoration of fertility (Table 3). The system of inheritance in this group appeared to be similar to that reported by Maunder and Pickett (1959), that a single gene termed 'MSc' for full fertility apart from minor modifiers, determined fertility restoration.

Group ii. Partially Dominant Major Gene Control: *S. subglabrescens* (Co. 18) *S. durra* (Co. 1) *S. dochna* (K. 3 and A. Ch. 121) and *S. caudatum* (A. S. 6199) did not seem to possess a dominant restorer for complete male-fertility. Fertility restoration in these types, was found to be determined by the cumulative action of partial restorers with major individual effect. Analysis of the segregation for male-fertility revealed that the inheritance of fertility restoration was digenic (Table 2). Two dominant genes for partial male-fertility appeared to restore full fertility when occurring together in homozygous condition (Table 3). The genetic mechanism in this group seems to be similar to that reported by Miller (1962) and Miller and Pickett (1964) where partial fertility was shown to be determined individually by the action of two major genes Pf_1 and Pf_2 in the presence of sterility inducing cytoplasm, their interaction resulting in 100 per cent male fertility.

Group iii. Modifir Gene Control: Fertility restoration in *S. nigricans* (A. S. 5823) and *S. nervosum* (A. S. 1741) appeared to be determined by the additive or complementary action of genes with small or no individual effect. The inheritance of male-fertility restoration in *S. nigricans* (A. S. 5823) in particular appeared to be determined by the action of two genes with additive or complementary action resulting in full fertility restoration in homozygous deminant condition (Table 3). This phenomenon in general agrees with the observation made by Kidd (1961) that, when three modifying genes were present, complete fertility restoration was attained. Genic complementation for fertility restoration, apparent in this group of *Sorghums* in the present study was also observed by Erichsen and Ross (1963) in the inheritance of colchicine induced cytoplasmic-genic male-sterile plants in *Sorghum*.

The failure of good fit to the Mendelian ratios in the inheritance of male-fertility has been observed by many investigators (Pi and Wu 1961, 1963; Kidd 1961) as in the case of the present study also. The ratios were also found to vary with environment. High temperature was found to alter a low fertile class into a high fertile class. Such response of male-fertility to environmental conditions is apt to result in distorted ratios. While the cytoplasmic-genic male-sterility was first discovered in *Sorghum* by Stephens and Holland (1954) it was felt that disturbance in seasonal conditions had rendered it impossible to estimate the number of genes involved in the inheritance of male-fertility restoration. Hadley and Singh (1961) found that the hybrid between m. s. C. K. 60 and *S. virgatum* was highly sterile in the green house during winter but partially fertile under field conditions.

3. *Genetic differentiation Eu-Sorghum:* Stephens and Holland (1954) observed that increasing doses of Kafir genome in 'Milo' cytoplasm progressively increased the expression of male-sterility finally resulting in a completely male-sterile line. The situation may be considered similar to the phenomenon observed in interspecific and inter-racial hybrids in *Epilobium* (Michaelis, 1954), where increasing doses of *E. hirsutum* geneome in *E. luteum* cytoplasm progressively increased sterility. The disturbance in the genic cytoplasmic harmony established through several generations of close breeding has presumably resulted in a loss or reduction in fertility in these cases. Stebbins (1958) while discussing about cytoplasmic-genic sterility observed 'that such a system of genic and cytoplasmic determiners of sterility could by segregation of appropriate combination in a single population, cause such population to become partially isolated reproductively from other populations of its species and so initiate speciation'.

In the present study, as well in those taken up by earlier investigators different patterns of inheritance for fertility restoration and absence of clear cut ratios due to setting up of modifier complexes have been observed in the crosses of various *Sorghum* types with m. s. C. K. 60. Break down of fertility in crosses between the two species of Snowden (1936) *S.roxburghii* (A. S. 3880) and *S. subglabrescens* (Co. 18) has also been observed indicating that free interbreeding is interferred with, although no gross meiotic abnormalities could be detected in these hybrids (Appadurai 1965).

The above results indicate that the mechanism for differentiation as propounded by Stebbins may be operative in the *Sorghum* types under study at present.

Summary: Twenty two *Sorghum* types representing different species of Snowden (1936) were tested for fertility restoration in crosses with male-sterile Combine Kafir-60. All the types restored fertility, though differences in the degree of restoration were observed.

The inheritance of fertility restoration in m. s. C. K. 60 was followed up in eleven of the crosses referred above by studying the F_2 and test-crosses of the F_1, with m. s. C. K. 60. Based on the segregation for fertility restoration, the crosses fell under three broad groups of inheritance pattern.

Fertility in four *Sorghum* types appeared to be under dominant major gene control. In five types fertility appeared to be the result of the cumulative action of partial restorers with major effect. Fertility in two types appeared to be determined by the action of genes with little or minor individual effect, complementing or adding to that of one another.

The diverse pattern of segregation for male fertility exhibited by crosses involving different *Sorghum* types on the same seed parent and the absence of clear cut ratios due to setting up of modifier complexes are indicative of Genetic differentiation within the sub-genus *Eu-Sorghum.*

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Heterosis in Wheat

by

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The value of heterosis is known since ancient times to animal breeders. Considerable interest has been generated during recent years in the exploitation of hybrid vigour in crop improvement. The utilization of heterosis appears to be quick, cheap and easy method of increasing yield in vegetatively propagated crops and in cross-fertilized crops like maize, pearlmillet, *sorghum*, onion *etc.* But little use has been made of heterosis breeding in self-fertilized crops. The development of genetic and chemical methods of emasculation (Pal and Sikka, 1956) has brought economic production of hybrid seed in self-fertilized crops into the realm of probability. Recent studies in barley (Jain and Allard, 1960), in Mungbean (Bhatnagar and Singh, 1964) have suggested that heterozygote advantage might be met with in self-fertilized crops also. While studying a large number of economic crosses it was considered desirable to investigate whether any heterosis could be exhibited by crosses among different pure lines of wheat.

Review of literature: Observations on heterosis in wheat date back to 1919, when Freeman studied date of first head, height and leaf width in crosses involving a *durum* wheat and three common wheats. Engledow and

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