THE INHERITANCE OF SOME CHARACTERS IN CROSSES WITH THE SORGHUMS, MILO AND KAFIR.

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The experiences gained in the inheritance of characters in sorghum from a cross made between the varieties Kafir (*Sorghum caffrorum*, Beauv.) and Milo (*Sorghum caudatum*, Stapf.) are presented in this article. These varieties were imported from America.

Kafir.—The Kafirs are native to Eastern Africa and are found distributed from Abyssinia to Natal. They were first introduced into the United States of America in 1875 when they were called *Milo maize* or *African Millet*. In 1886 they were introduced into the Great Plains region of America where they were extensively cultivated. The plants are stout with numerous leaves and overlapping leaf-sheaths. They have juicy and sweet stalks. They do not lodge or sucker. With their uniform height and straight, rod-like panicles, the Kafirs form a well-defined group of low, stout, stocky, heavily seeded plants. In this heavy seeding they will fall in the Grain Sorghum group though in the grains being mostly enclosed by the glumes their affinities are with the sweet sorghums. They are generally late maturing—120 to 130 days—but in the varieties *Dawn Kafir* and *Sunrise Kafir*, the earheads ripen in 110–115 days. The height of the plants ranges from 4 to 7 feet according to the variety. There are 14–16 leaves, all of which persist and remain green even after the ripening of the earheads. There are many varieties of Kafir and the particular variety figuring in this cross is *Blackhull Kafir.*

Milo.—The Milo is the other parent of the cross. The original strain—*Standard Yellow Milo*—was introduced into the United States of America from North Africa about 1880. Two shorter strains known as *Dwarf*, and *Double Dwarf Milo* are also grown. Standard Milo grows to a height of 5–6 feet, Dwarf 3–4 feet and Double Dwarf 1½–2 feet. The Dwarfs are mutants from the Standard variety. The Milos have compact, elliptic earheads, borne on comparatively thin, pithy stalks bearing 12 leaves. They tiller freely and mature in 95–110 days. The grain is very bold, well

exserted from the glumes and more brittle than Kafir. Though called "Yellow" Milo the grain is pink (a dilute red) in colour. The same three heights that occur in Yellow Milo exist also in white varieties—the white grains having red bases.

The inheritance of the following contrasting characters is presented below :—

Contrasting character	Varieties	
	Kafir	Milo
Disposition of the leaf-blade	Flat	Wavy
Disposition of the specialised tissue at the junction of the leaf-blade and the leaf sheath	Smooth	Corrugated
Desiccation of the edges of leaves ..	Non-drying	Drying
Shape of grain	Umbonate	Round
Colour of subule*	..	Purple

Disposition of the leaf-blade.—The leaf-blades in the majority of sorghums are thrown into curves at their margins. This gives a characteristic waviness to the leaf-blades of sorghum (Fig. 1). Rarely, as in the Kafirs, the leaf-blades do not have this wavy appearance but have a smooth and flat disposition (Fig. 2). These flat leaf-blades of Kafir are a marked varietal characteristic. With a given length of midrib and a marginal length to suit, the flat leaf-blade results. With the same length of midrib, if the leaf-margin is longer, the margin has necessarily to be thrown into folds to accommodate itself. The relative proportions of midrib and marginal lengths in 20 flat and 20 wavy leaves are presented in the following table (Table I).

In Table I the longer length of the leaf-margin of wavy leaf-blades will be obvious.

In the cross between the two types of leaf-blades, the F_1 generation blades were all wavy. In the F_2, waviness was found to behave as a simple

* *N.B.*—Milo is awned. Kafir is awnless. The subule in the awn of Milo is coloured purple. The inheritance of this peculiarity has been pursued in crosses with an awned variety, *Chinna Manjal Cholam* (*Sorghum Durra,* Stapf.).

TABLE I.

Measurements of third leaf from top.

Leaf-blade			
Wavy (Milo)		Flat (Kafir)	
Midrib	Leaf-margin	Midrib	Leaf-margin
1	2·51	1	2·16
1	2·49	1	2·15
1	2·45	1	2·15
1	2·44	1	2·14
1	2·44	1	2·14
1	2·44	1	2·14
1	2·44	1	2·14
1	2·43	1	2·14
1	2·43	1	2·14
1	2·43	1	2·13
1	2·43	1	2·13
1	2·43	1	2·13
1	2·41	1	2·13
1	2·39	1	2·13
1	2·39	1	2·13
1	2·37	1	2·12
1	2·36	1	2·12
1	2·35	1	2·12
1	2·34	1	2·11
1	2·33	1	2·11
Average *1*	*2·41*	*1*	*2·13*

dominant to the flat condition. A factor *Mu* brings about the undulating margins of the wavy leaves. Factor *mu* results in the flat leaf.

TABLE II.

Segregation for wavy and flat leaf-blades.

Selection Numbers	Leaf-blades	
	Wavy (Milo)	Flat (Kafir)
A. S. 3717, 3718, 3719, 3720	605	201

Among the Indian sorghums, in two selections belonging to *Sorghum cernuum*, Host., the following segregations for this waviness were also met with.

TABLE III.

Segregation for Wavy and Flat Leaf-blades.

(Sorghum cernuum, *Host.*)

Varietal Name	Selection Numbers	Leaf-blades	
		Wavy	Flat
Ramkel Juar	A. S. 3366	119	40
Adhroo Juar	A. S. 3781	89	26
	Total ..	208	66

In these two Indian varieties, it was noticed that the plant with flat leaf-blades had smaller panicles, thinner stalks and narrower leaves than those with wavy leaves. Measurements were recorded for these characters and are given in the accompanying tables (Tables IV to VII).

It will be seen from the data presented above that the panicles are smaller, culms thinner and leaves narrower in plants with flat leaves. The wavy leaf is associated with big panicles, broad leaves and a thick stalk. These economic advantages help us to understand the preponderance of wavy leaved varieties in Grain Sorghums and the paucity of flat leaved ones. *A single gene affecting a qualitative character, like the disposition of the leaf-margin, is thus closely associated with a group of developmental effects resulting in a vigorous plant.*

TABLE IV.

Panicle Length.

	A. S. 3366											A. S. 3781															
Centimetres	13	14	15	16	17	18	19	20	21	22	23	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Wavy ..	—	—	5	7	17	19	16	20	18	11	6	—	1	—	—	1	12	10	12	19	10	12	3	4	1	3	1
Flat ..	2	4	10	12	7	4	1	—	—	—	—	3	1	2	7	7	2	1	2	1	—	—	—	—	—	—	—

	A. S. 3366	A. S. 3781
	cm.	cm.
Wavy — Mean length	20·8	22·1
Flat — Mean length	15·8	17·5
	P > ·01	P > ·01

TABLE V.

Panicle Thickness

(at the greatest width).

	A. S. 3366								A. S. 3781									
Centimetres	3	4	5	6	7	8	9	10	3	4	5	6	7	8	9	10	11	12
Wavy ..	—	—	21	28	36	24	9	1	—	—	2	14	26	22	16	5	2	2
Flat ..	1	9	21	6	2	1	—	—	1	6	10	6	1	2	—	—	—	—

	A. S. 3366	A. S. 3781
	cm.	cm.
Wavy — Mean thickness	6·8	7·8
Flat — Mean thickness	5·1	5·2
	P > ·01	P > ·01

TABLE VI.

Minimum diameter of the third internode from top.

	A. S. 3366											A. S. 3781													
Millimetres	7	8	9	10	11	12	13	14	15	16	17	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Wavy ..	—	—	—	9	22	22	24	16	11	10	4	—	—	—	—	2	11	18	15	15	13	7	5	2	1
Flat ..	2	—	6	20	9	1	—	1	—	—	—	1	1	6	4	7	3	3	1	—	—	—	—	—	—

	A. S. 3366	A. S. 3781
	mm.	mm.
Wavy — Mean diameter	13	15
Flat — Mean diameter	10	11
	P > ·01	P < ·01

TABLE VII.

Maximum width of third leaf from top.

	A. S. 3366										A. S. 3781									
Centimetres	5·6 to 6·0	6·1 to 6·5	6·6 to 7·0	7·1 to 7·5	7·6 to 8·0	8·1 to 8·5	8·6 to 9·0	9·1 to 9·5	9·6 to 10·0	10·1 to 10·5	5·6 to 6·0	6·1 to 6·5	6·6 to 7·0	7·1 to 7·5	7·6 to 8·0	8·1 to 8·5	8·6 to 9·0	9·1 to 9·5	9·6 to 10·0	10·1 to 10·5
Wavy ..	—	1	2	13	11	17	33	19	13	9	—	—	4	6	19	19	16	16	8	2
Flat ..	2	4	10	15	4	3	1	—	—	—	6	9	5	5	4	1	—	—	—	—

	A. S. 3366	A. S. 3781
	cm.	cm.
Wavy — Mean width ..	8·6	8·5
Flat — Mean width ..	7·1	6·7
	P > ·01	P > ·01

Corrugation in leaf-junction.—The leaf-blade is inserted on to the top of the leaf-sheath through a tough specialised, lighter coloured, triangular, auricular tissue, called the *junction*. The leaf-blades slightly narrow down as they reach the top margin of the junction. When the blade is wide, the junction runs into folds both at the edge and on its surface (Fig. 3) and thus accommodates the connection with the sheath. Measurements taken of the contour of the corrugations in 20 junctions show that there is a 25 per cent. increase of surface area in this junction, which a compression in the usual junction space throws into folds. The Kafir has a smooth junction and the Milo a corrugated one. In the F_1 plants of the cross between Kafir and Milo, the junctions were smooth. In the F_2, segregations were obtained for smooth and corrugated junctions showing that the corrugated condition behaves as a simple recessive. This peculiarity of the junction that results in corrugation is due to a factor *jc*, the usual flat junction being due to the presence of *Jc*.

TABLE VIII.

Segregation for leaf-junction corrugation.

Selection Numbers	Leaf-junctions (auricular)	
	Smooth (Kafir)	Corrugated (Milo)
A. S. 3717, 3718, 3719, 3720	616	190

The leaf-margins and leaf-junctions of a number of varieties were examined. Whereas leaves with wavy margins could have junctions smooth or corrugated, flat leaves had almost always smooth junctions.

Desiccation of edges of leaves.—In sorghums the leaf-edges do not usually dry up. They dry up in the Milos. In the "Yellow" Milo, being pink-grained, a red sap colour is developed in the edges and shows off the desiccation (Fig. 4). In white grained Milos the leaf-edges dry to a brownish straw colour. This colour is developed after flowering ceases and is best seen in the pre-ripening stages of the grain. The dried belt, whether reddish or straw coloured, is well defined and is about a centimetre wide. This localised desiccation is different from the common whole leaf desiccation prevalent in the black soil tracts of the Deccan (India). The Kafirs do not develop this dry edge colour. In the crosses between these two varieties—Kafirs and Milo—the F_1 plants developed reddish coloured dry leaf edges. In

the F_2, the drying in the edge was found to behave as a simple dominant to the non-drying state. The desiccated condition of the edges of the leaf arises from the presence of a factor named *Md*. Factor *md* gives the common experience of leaves whose edges do not dry.

TABLE IX.

Segregation for leaf-edge drying.

Selection Numbers	Leaf-edges	
	Drying	Non-drying
A. S. 3717, 3718. 3719, 3720	475	164

To see the effect of this leaf-edge drying character peculiar to Milo, on a local variety, a cross was made between Milo and *Chinna Manjal Cholam* (*Sorghum Durra*, Stapf.). The F_1 plants had leaves with edges drying and the F_2 segregated giving the usual monogenic segregation.

Shape of Grain.—The grain in Kafir is broad-elliptic, slightly exceeding the glumes. The area enclosed by the glumes is here much higher than in Grain Sorghums and partly accounts for the elliptic shape with acute tips. In the general build of the head and the exsertion of the grain, the Kafirs resemble the Chinese sorghums (*Sorghum Nervosum*, Bess.) and their nearest South Indian ally, the *Irungu*, but in the Kafirs the exsertion of the grain is a bit more than in the *Irungu*. The tip of the Kafir grain is acute. The grain is not symmetrical about the axis and is developed more to one side. It is umbonate (Fig. 5). The grains are elliptic and not obovate as in Milo. The style bases are contiguous and not apart as in Milo.

The Milo grain is bold, well exserted, with obovate-orbicular grain tops. The stylar bases are apart. The grain is more or less symmetrical about the axis. In crosses between Kafir and Milo, the F_1 plants had umbonate grains. In the F_2, umbonateness proved a simple dominant to the usual obovateness of the Grain Sorghum (Table X). The umbonate shape occurs due to the presence of a factor *U*. Grains not umbonate have the factor *u*.

TABLE X.

Segregation for grain shape.

Selection Numbers	Grain Shape	
	Umbonate	Round
A. S. 3717, 3718, 3720	328	121

Colour of Subule.—The sorghum awn has two parts (1) the *column*, which is usually coloured brown and is twisted once or twice, and (2) the *subule* which is barbate and usually colourless. The Milos are peculiar in having purple subules. In pure lines, the colour in the subule can be noted in stray awns even at the emergence of the panicle. By the time the panicle finishes flowering, 90–95 per cent. of the subules are coloured purple. The best time to observe this character is therefore when the earhead is in full flower.

Purple subules being a rarity in sorghum, the inheritance of this character was sought to be pursued. Since Kafir is awnless, the inheritance of this peculiarity of Milo could be pursued only in a cross between Milo and *Chinna Manjal Cholam*, a local variety of *Sorghum Durra*, Stapf. The F_1 plants had coloured subules. In the F_2, the purple pigment in the subule was found to behave as a simple dominant to the non-pigmented state of the subule. The awns get purple tipped due to a factor *Ap*; factor *ap* gives colourless awn-tips.

TABLE XI.

Segregation for subular colour.

Selection Number	Subular colour	
	Purple	Non-purple
A. S. 3726	91	33

Cross Collations.—In Milo-Kafir crosses, the grains segregate into Pink (RRiiYYWW) and White (RRiiYYww). In the cross for the study of awns with purple subule, the grains segregated into Red (RRIIYYWW), Pink (RRiiYYWW) and Yellow (rrIIYYWW and rriiYYWW) (Rangaswami Ayyangar *et al.*, 1933).[1] Cross collations were made between the four characters: Leaf-margin waviness (*Mu*), Leaf-edge drying (*Md*), Junction

corrugation (*Jc*), and Shape of grain (*U*), and all these four and grain colour. The collations are presented in the following Tables.

TABLE XII.

Wavy leaf-blades and Grain Colour.

Selection Numbers	Grain Colour	Leaf-blades			
		Wavy		Flat	
		Pink	White	Pink	White
A. S. 3717		55	13	23	8
A. S. 3719		82	21	33	9
A. S. 3720		61	12	17	1
Total (observed)		198	46	73	18
,, (calculated) 9 : 3 : 3 : 1		188	63	63	21

$X^2 = 7 \cdot 13$ $P > \cdot 05$

TABLE XIII.

Wavy leaf-blades and leaf-edge drying.

Selection Numbers	Leaf-edges	Leaf-blades			
		Wavy		Flat	
		Drying	Non-drying	Drying	Non-drying
A. S. 3718		150	36	57	28
A. S. 3719		80	38	34	15
A. S. 3720		66	15	16	5
Total (observed)		296	89	107	48
,, (calculated) 9 : 3 : 3 : 1		304	101	101	34

$X^2 = 7 \cdot 74$ $P > \cdot 05$

From the above tables it will be seen that *Mu* is independent of the factors *W* and *Md*.

TABLE XIV.

Leaf-junction corrugation and Grain Colour.

Selection Numbers	Grain colour	Leaf-junction			
		Smooth		Corrugated	
		Pink	White	Pink	White
A. S. 3717		55	17	23	4
A. S. 3718		140	47	52	11
A. S. 3719		83	18	31	12
Total (observed)		278	82	116	27
,, (calculated) 9 : 3 : 3 : 1		284	94	94	31

$X^2 = 7 \cdot 32$ $P > \cdot 05$

TABLE XV.

Leaf-junction corrugation and leaf-edge drying.

Selection Numbers	Leaf-edges	Leaf-junction			
		Smooth		Corrugated	
		Drying	Non-drying	Drying	Non-drying
A. S. 3717		49	27	20	6
A. S. 3718		147	50	60	14
A. S. 3719		83	39	31	13
A. S. 3720		60	13	23	6
Total (observed)		339	129	134	39
,, (calculated) 9 : 3 : 3 : 1		360	120	120	40

$X^2 = 3 \cdot 56$ $P > \cdot 05$

It will be seen that the factor *Jc* segregates independent of *W* and *Md*.

TABLE XVI.

Leaf-edge drying and Grain Colour.

Selection Numbers	Grain colour	Leaf-edges					
		Drying			Non-drying		
		Red	Pink	Yellow	Red	Pink	Yellow
A. S. 3724		54	9	10	11	8	6
A. S. 3726		57	18	24	12	3	11
Total (observed)		111	27	34	23	11	17
,, (calculated) 27: 9: 12: 9: 3: 4		94	31	42	31	10	14

$X^2 = 7{\cdot}93$ $P > {\cdot}05$

TABLE XVII.

Leaf-edge drying and wavy leaf-blades.

Selection Numbers	Leaf-blades	Leaf-edges			
		Drying		Non-drying	
		Wavy	Flat	Wavy	Flat
A. S. 3718		150	57	36	28
A. S. 3719		80	34	38	15
A. S. 3720		66	16	15	5
Total (observed)		296	89	107	48
,, (calculated) 9: 3: 3: 1		304	101	101	34

$X^2 = 7{\cdot}74$ $P > {\cdot}05$

TABLE XVIII.

Leaf-edge drying and Leaf-junction corrugation.

Selection Numbers	Leaf-junction	Leaf-edges			
		Drying		Non-drying	
		Smooth	Corrugated	Smooth	Corrugated
A. S. 3717		49	20	27	6
A. S. 3718		147	60	50	14
A. S. 3719		83	31	39	13
A. S. 3720		60	23	13	6
Total (observed)		339	134	129	39
,, (calculated) 9 : 3 : 3 : 1		360	120	120	40

$X^2 = 3 \cdot 56 \quad P > \cdot 05$

That factor *Md* behaves independent of the factors *R*, *I*, *Mu*, and *Jc* will be obvious from the above tables.

TABLE XIX.

Shape and Colour of Grain.

Selection Numbers	Grain colour	Shape of Grain			
		Umbonate		Round	
		Pink	White	Pink	White
A. S. 3717		55	15	23	5
A. S. 3718		147	48	54	11
A. S. 3719		77	16	39	13
Total (observed)		279	79	116	29
,, (calculated) 9 : 3 : 3 : 1		284	94	94	31

$X^2 = 7 \cdot 76 \quad P > \cdot 05$

The factor *U* behaves independently of *W*.

TABLE XX.

Purple subule and Colour of Grain.

Selection Numbers	Grain colour	Subule Colour					
		Purple			Non-purple		
		Red	Pink	Yellow	Red	Pink	Yellow
A. S. 3724		47	13	5	19	3	11
A. S. 3726		47	17	27	22	4	7
Total (observed)		94	30	32	41	7	18
,, (calculated) 27 : 9 : 12 : 9 : 3 : 4		94	31	42	31	10	14

$X^2 = 7 \cdot 68 \quad P > \cdot 05$

TABLE XXI.

Purple subule and Leaf-edge drying.

Selection Numbers	Leaf-edges	Subular Colour			
		Purple		Non-purple	
		Drying	Non-drying	Drying	Non-drying
A. S. 3724		49	17	26	8
A. S. 3726		74	17	23	10
Total (observed)		123	34	49	18
,, (calculated) 9 : 3 : 3 : 1		126	42	42	14

$X^2 = 3 \cdot 9 \quad P > \cdot 05$

The ratios of 27 : 9 : 12 : 9 : 3 : 4 of Tables XVI and XX are interesting.

With reference to awns with purple subules, the grain segregation was into red, pink and yellow, and the cross collations of purple awn in all the three groups proved *AP* to be independent of *R* and *I* in inheritance (Table XX). *Ap* is also independent of *Md*.

Summary.

Data on the inheritance of a few characters from a cross between Blackhull Kafir (*S. caffrorum*, Beauv.) and Dwarf Yellow Milo (*S. caudatum*, Stapf.) are presented. (1) The margins of leaf-blades are wavy in Milo and flat in Kafir. Waviness (*Mu*) is a simple dominant to flatness (*mu*). Segregations for wavy and flat leaf-blades have also been obtained in selections of *S. cernuum*, Host., with the remarkable going together of a general all-round vigour with wavy-leaved plants. (2) The leaf-edge of Milo dries up to a width of about a centimetre. In Kafir the leaf continues to be green. A factor *Md* inducing drying is a simple dominant to *md* giving non-desiccated edges. (3) The specialised tissue at the junction between the leaf-blade and the leaf-sheath is smooth in Kafir (as in most varieties). In Milo this junction is corrugated. Smooth junction (*Jc*) is a simple dominant to corrugated junction (*jc*). (4) In Kafir the grains that are very much enclosed within the glumes are umbonate in shape. In Milo (as in most Grain-Sorghums) the grain is obovate with broadly rounded tops. A factor *U* gives umbonate grains and in its absence (*u*) round topped grains are produced. (5) Kafir has no awns. Milo is awned. The awns of Milo are peculiar in having their subules coloured purple. In almost all varieties the subule is colourless. Crosses between Milo and *S. Durra* (colourless subule) show that the coloured subule (*Ap*) is a simple dominant to the colourless subule (*ap*). (6) Cross collations show that *Mu* and *Jc* are independent of the grain colour factor *W* and of *Md*. The factor *Md* operates independently of the grain colour factors *R* and *I* and of factors *Mu* and *Jc*. Factor *U* does not affect *W*. Factor *Ap* behaves in inheritance independently of *R*, *I* and *Md*.

REFERENCE.

1 Rangaswami Ayyangar, G. N., *et al.*, *Ind. J. Agr. Sci.*, 1933, **3**, 594–604.

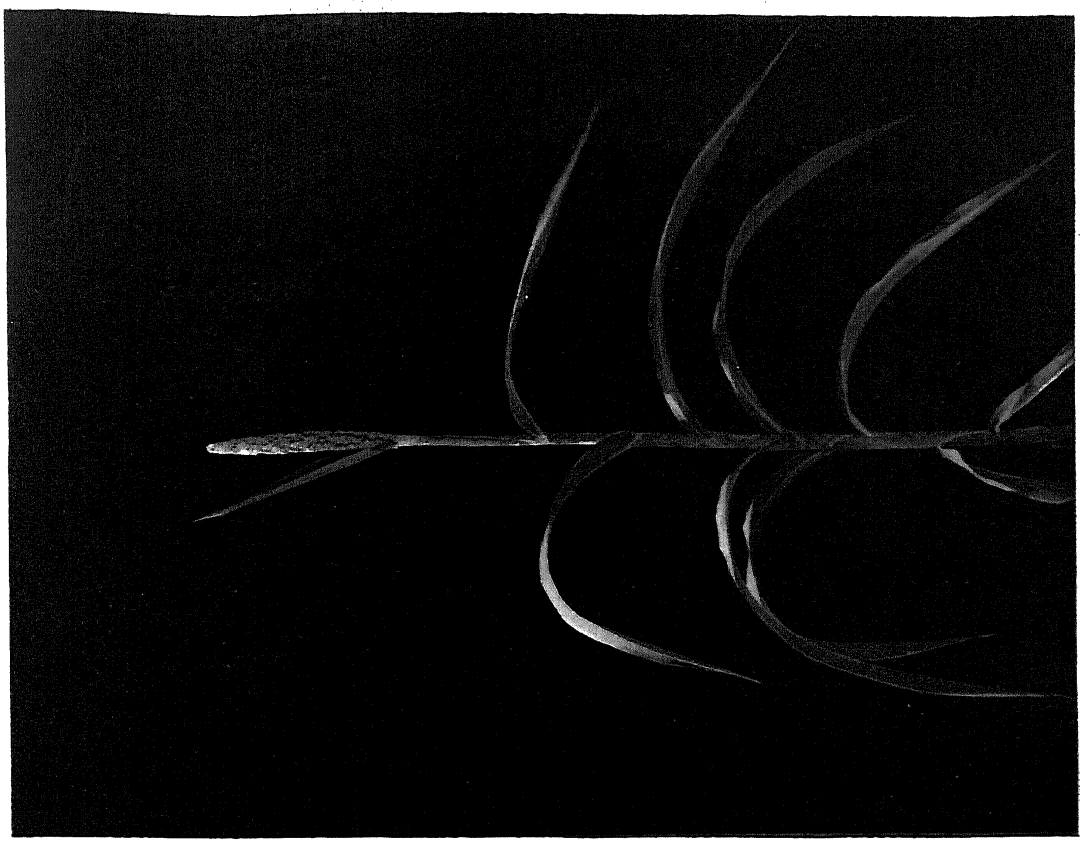


FIG. 2.
Flat leaved plant.

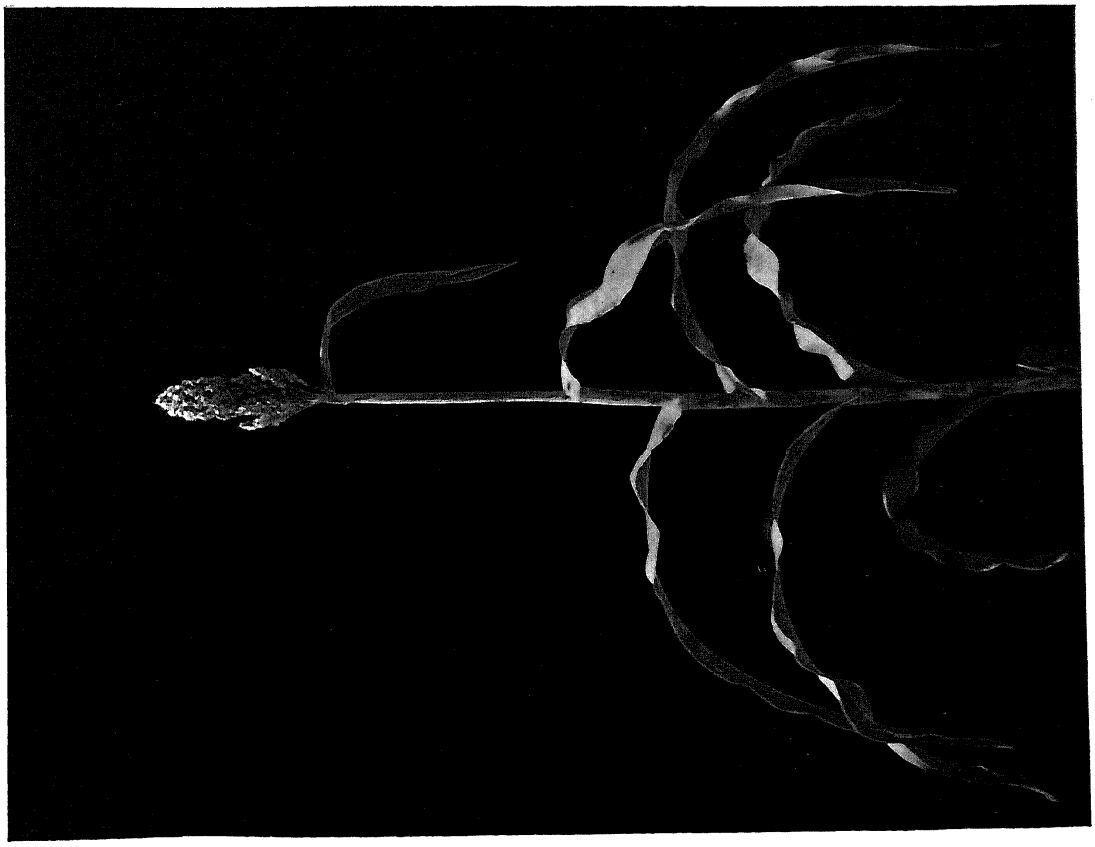
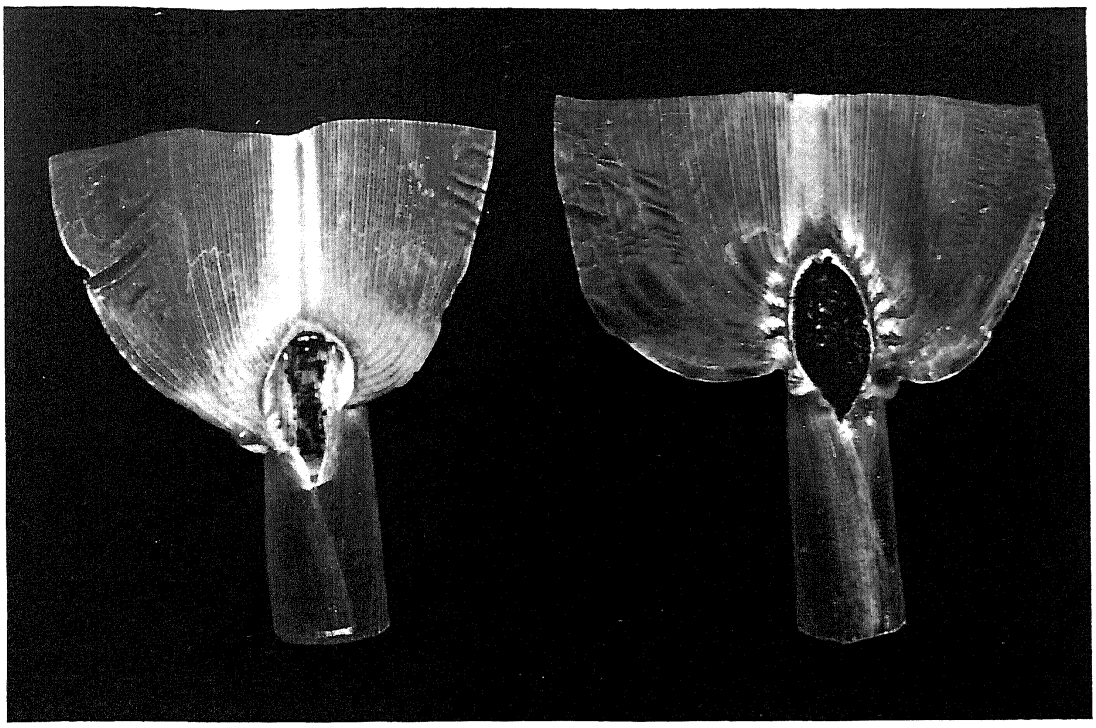


FIG. 1.
Wavy leaved plant.



Smooth Corrugated

FIG. 3.
Leaf-junctions.

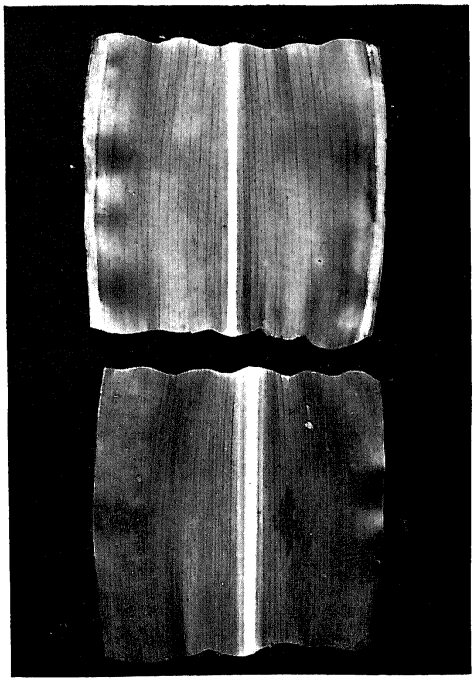


FIG. 4.
Top. Desiccated leaf-edges.
Bottom. Normal leaf-edges.

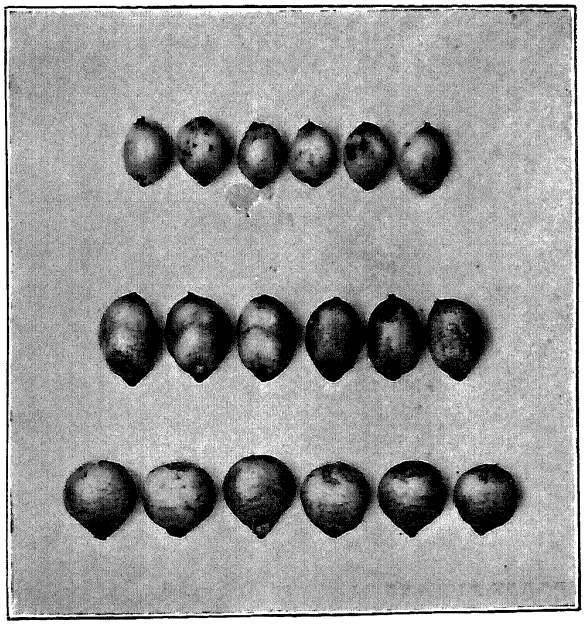


FIG. 5.
Top. Umbonate grains of Kafir.
Middle. F_1 grains (umbonate).
Bottom. Obovate, round topped grains of Milo.