

# STUDIES IN *SORGHUM SUDANENSE*, STAPF—THE SUDAN GRASS

BY G. N. RANGASWAMI AYYANGAR, F.N.I., I.A.S.

*Millets Specialist and Geneticist*

AND

B. W. X. PONNAIYA, B.Sc., AG.

(Assistant, Millets Breeding Station, Coimbatore)

Received December 7, 1938

## *Introduction*

SUDAN GRASS is a Grass Sorghum introduced into America from the Sudan. Its importance is because of its high forage value in America and also in other parts of the world. *S. sudanense* belongs to the series *Spontanea*, sub-section *Arundinacea*, in the *Eu-sorghum* section of the genus *Sorghum*.<sup>1</sup> Snowden after an intensive examination of several sorghums, both wild and cultivated, comes to the conclusion that the cultivated sorghums belonging to the sub-series *Bicoloria* in the series *Sativa* (also of sub-section *Arundinacea*) are the products of some combination of *S. æthiopicum* (Hack.) Rupr. ex. Stapf and *S. sudanense*, Stapf. He thinks it probable that in view of the close affinities, *S. dochna* (of the sub-series *Bicoloria*) owes its origin very largely to *S. sudanense*.

The reasons for this probable contribution of *S. sudanense* to the origin of some races of cultivated sorghum are (1) its ready crossing with cultivated sorghums and the large number of grain sorghum natural crosses that occur in it, (2) its tough racemes, (3) the persistent pedicelled spikelets,<sup>2</sup> (4) the absence of deciduousness of sessile spikelets through callus formation,<sup>3</sup> (5) size and shape of sessile spikelets, (6) the arrangement of the spikelets in the panicle, (7) time of anthesis,<sup>4</sup> and (8) absence of hard seeds.

The studies presented in this paper represent experiences gained in the course of the examination of crops raised from fifty seed samples from various sources, including forty from Russia, during the last five years.

## *Agro-Botanical Description*

*Duration*—80 to 110 days; *Seedlings*—coleoptile deep purple, purple, or green<sup>5</sup>; *Seedling-leaves*—bluish green or green<sup>6</sup>; *Leaf-sheath*—blackish-purple<sup>7</sup>; *Nodal band*—purple, stray cases green<sup>8</sup>; *Axil of leaf-sheath above*

*nodal band*—purple, stray cases green; *Auricular junction*—purple, stray cases green; *Midrib*—white<sup>9</sup>; *Awn*—long 9 to 11 mm., stray cases nil; *Stigma*—very light yellow; *Anther*—(fresh), very light yellow, (dry) very light brown<sup>10</sup>; *Grain*—brown in colour, enclosed in glumes; *Glume*—bleached blackish purple, stray cases unbleached; *Panicle*—loose conical, secondary branches adpressed (occasionally diverging), tertiary branches absent in some cases; *Spikelets*—arranged in a cymose fashion; *Emergence*—good, about 15 cm.; *Peduncle*—about 40 cm. long, hollow just immediately below the panicle; *Tillers*—15 to 20, the main and primary tillers (almost contemporary to it) are both unimodal in internodal disposition, the late tillers arising from the primary tillers are however of the uniform increasing type<sup>11</sup>; *Bloom*—very sparse, stray cases apparently nil.<sup>12</sup>

The studies on this Sudan grass could be grouped into (1) rare characters that are common to *S. sudanense* and *S. dochna* (more a fodder than a grain sorghum), (2) characters experienced so far in Sudan grass only, and (3) those that are of evolutionary interest.

*Rare Characters that are Common to S. sudanense and S. dochna*—

*E-ligulate and Non-auriculate Condition of the Leaves*.—In a previous publication it has been recorded that the *e-ligulate* and non-auriculate condition in Sudan grass (gene *lg*) is a simple recessive to the ligulate and auriculate condition<sup>14</sup> (*Lg*). In many of the extracted types of Sudan grass from Russia an *e-ligulate* condition prevails. When it occurs, the plant assumes an erect habit and looks compact and rigid (Fig. 1) and the earheads are rod-like. As in cultivated sorghums, in Sudan grass also, when the ligule and auricle are absent, the pulvinus is absent (Fig. 3) and there is a shortening in the spikelet-free area in the base of panicle branches and branchlets.<sup>15</sup> This leads to a compact head with panicle branches overcrowded with spikelets. The contrast between a loose head from a ligulate and auriculate plant and a compact head from an *e-ligulate* non-auriculate plant, is well brought out in Fig. 2. The occurrence of the *e-ligulate* condition has been recorded in *S. sudanense* and in Broom corn (*S. dochna* var. *technicum*). This concurrent manifestation of the same rare character in both these sorghums is very significant in the support that it gives about the contribution of *S. sudanense* to the evolution of *S. dochna*.

*Compact-spindle Panicle*.—Being a 'wild' sorghum the panicle in Sudan grass is usually loose and conical. A rare heterozygous mutation was met with in family No. S. 75 (Guntur collection) in which there occurred a segregation for panicle shape only, giving 161 plants with loose conical

panicles and 48 with compact spindle-shaped ones. The unusual occurrence of this compact spindle (not the compactness associated with the E-ligulate condition) in this grass is significant. This type of panicle ( $Pa_1$ ) has been reported upon in *S. dochna*.<sup>16</sup> This lends a second evidence to its affinity to *S. dochna*.

*Pedicelled Spikelets with a Wash of Purple.*—The pedicelled spikelets in sorghum are usually unpigmented. They are green when fresh and straw-coloured when dry. In red-grained sorghums where the sap colour invades even the pedicelled spikelets, a tap of the ripe head will dislodge a number of red coloured pedicelled spikelets. This is one of the characters in the sap colour series associated with red-coloured grains.<sup>8</sup> In the case of the P and Q factor manifestations of purple pigments, *i.e.*, reddish-purple and blackish-purple of leaf-sheath and glume,<sup>7</sup> the pigment never shows well on the glumes of pedicelled spikelets. There is another type of manifestation of purple pigment which is related to P and Q and which shows in certain African varieties only, even on the emergence of the panicle from the boot.<sup>17</sup>

In most of the Sudan grasses a new type of manifestation of purple pigment (not of the P type) is met with. It is the presence of this type of pigment that gives the characteristic purple-washed appearance to a fresh panicle beginning to flower. The purple-wash is seen on the first glume of the pedicelled spikelet which is the one that is most exposed to the sun. When so exposed, the second glume is also coloured. The colour is deeper at the base of the glume and is best seen at flowering time, but it disappears at about the dough stage of the grain. This special manifestation of purple pigment is peculiar to Sudan grass. A gene designated PW is responsible for the manifestation of the purple pigment mostly on the exposed first glume of the pedicelled spikelet in Sudan grass. In the  $F_2$ , of family No. S. 75 (Guntur collection) there was a 3 : 1 segregation with 154 purple-washed spikelets and 58 green spikelets. It is interesting to note that this additional purple dominant gene which has dropped out in most of the cultivated sorghums<sup>17, 18, 19</sup> has been met with in Africa, an additional evidence of its being the home of sorghum. This character was also met with in certain varieties of *S. dochna* from China. The occurrence of this phenomenon in *S. dochna* is an additional and third evidence for the probability of *S. sudanense* being a progenitor of the *S. dochna* group of cultivated sorghums.

*Characters Experienced in Sudan Grass Only—*

*Banded-seedlings.*—Seedlings with chlorophyll deficient bands have occurred in Sudan grass (Guntur collection). The bands are prominent in

the broad first seedling-leaf.<sup>20</sup> They are white and are devoid of chlorophyll. The band may be at the tip, top, middle or at the sides of the first seedling leaf. It is usually in a single and occasionally in more than one band. The bands are 1 to 2 mm. wide. They may show in the second seedling leaf also. This character expresses in seedling-leaves only. In stray cases the lower leaves in a tiller have repeated this experience. The adult plants do not give a clue to this character. In crosses between banded and normal varieties, the normal green condition proved a simple dominant character. The  $F_2$  segregation gave 317 non-banded seedlings and 100 banded seedlings. A gene designated *cb* is responsible for inducing albinotic bands in the seedling leaves of Sudan grass.

*Seedling Habit.*—A study of seedlings in seed-pans shows that sorghum seedlings differ in habit. These differences are minute in grain sorghums. In Sudan grass with its characteristic tillering, seedling habit differences have however been perpetuated graphically. There are pure lines in which the seedlings have a spread-out habit, the tillers making an angle of about  $45^\circ$  with ground level. There are other pure lines in which the tillers are practically erect. This seedling habit is best seen when the seedlings are about 4 to 5 weeks old. It gets obscure on and after flowering. In crosses between the two types (Guntur collection) the open habit has proved a simple dominant to the erect habit. In the  $F_2$  generation (family No. S. 86) 86 open and 30 erect seedlings were obtained. A gene designated *SO* produces seedlings with an open habit.

*Striping of Leaves.*—Regular striping in leaves is often pathological in origin.<sup>21</sup> Irregular and erratic stripes are aspects of maternal inheritance.<sup>22</sup> True breeding types with faint and regular white longitudinal stripes on the leaf-blades have been recorded by Russian workers.<sup>23</sup> They note that such plants were weak. Unlike their experience, which was probably due to poor populations good monogenic segregations have been obtained between normal green and striped leaves, the figures from three segregating selections from family No. S. 173 from Russia being 130 and 32, 200 and 65, and 125 and 40 respectively. A gene designated *cs* produces leaf-blades with thin white stripes. It is interesting to record the fact that when the leaves are striped, a few glumes exhibit a similar striping.

*Bloom.*—In a previous paper the occurrence and inheritance of waxy bloom has been recorded.<sup>12</sup> Heavy bloom is a simple dominant to sparse bloom. It was then stated that the wild sorghum group in which was included *S. sudanense* shows a distribution of bloom that is more sparse than in the grain sorghums. The examination of many lines of Sudan grass

shows that, whereas the bloom is very sparse in the majority of types, there occur types in the Guntur collection with a still sparser manifestation of bloom, bordering on absence. On the leaf-sheath (especially on the boot at flowering time) and on the internode, the normal Sudan grass has a very sparse coating of bloom. In the extremely sparse bloom condition, the internode is practically bloomless while the boot retains traces of bloom. Segregations have been obtained for the very sparse and extremely sparse condition of bloom, the total of five families in both  $F_2$  and  $F_3$  being 219 very sparse to 70 extremely sparse. Another dilution gene seems to determine the lightness of manifestation of the bloomy condition. The relationship of the four types is being worked out.

*Panicle.*—In this grass the primary branches of the panicle have pulvinii and make an angle with the central stalk. The secondary branches lack the pulvinii and are therefore practically adpressed to the primary branches. Whereas the majority of Sudan grasses have such adpressed secondary branches, there were found two pure lines one from Russia and another from Guntur in which the secondary branches had well marked pulvinii resulting in their being at about a right angle to the primary branches giving the earhead a fulness in look in contrast to the sketchy appearance of the usual type (Fig. 4). In crosses between the two types, the angular condition of the secondary branches has proved a simple dominant to the adpressed condition. In the  $F_2$  generation a monogenic segregation of 49 angular to 17 adpressed plants was obtained. This behaviour was in a loose conical type ( $Pa_1$ ), in which the primary branches with their marked pulvinii ramified from the central stalk and made it easy to pursue this character. The sparse-headed 'wild' sorghum has thus given a helpful clue to one of the constituents in panicle structure. A gene designated  $Pa_2$  thus determines the angular disposition of the secondary branches to the primary branch. In grain sorghums that are more highly evolved, other factors like compactness of the panicle and heaviness of the grain make it difficult to pursue easily the effect of this gene.

Another contribution that this 'wild' Sudan grass has to make to the understanding of panicle structure, is the light that it throws on the arrangement of the spikelets on the panicle. The sessile and pedicelled spikelets are arranged in the form of a cyme. All the sessile spikelets represent the main flower of the cyme and the pedicelled spikelets the lateral ones. The whole arrangement is dichasial but with an alternate development (Fig. 6). This explains why every sessile spikelet has a pedicelled one and the terminal sessile spikelet two pedicelled spikelets, one of which the ultimate,

has always a slightly longer pedicel than that of its mate. All the sorghums, whether wild or cultivated examined so far conform to the above description. In the cultivated sorghums this is not quite clear owing to the overcrowding of the spikelets. In a cyme the middle flower is the oldest and flowers first. This fact explains the second wave of anthesis of the pedicelled spikelets in the cultivated sorghums which has been described in great detail in a previous paper.<sup>24</sup>

A proliferated earhead occurred in family S. 52, a Sudan grass pure line from Guntur (Fig. 5). In this the lower panicle branches turned into vegetative shoots and thus evidenced the evolution of the panicle from foliar organs. It is noteworthy that some of the vegetative shoots however give out panicles once again from some of their axils.

#### *Characters of Evolutionary Interest—*

*Tillering.*—The tillering habit is an important attribute of the Gramineæ. A tussock is a product of heavy tillering. In the evolution of the cereals with their definite sowing and harvest time, a fairly uniform maturity of earheads is a requisite. Under crowded conditions, cereals can be few headed, provided they are fairly uniform in duration. In sorghum a practically single stalked condition has been bred up from a many tillered condition by not giving full scope for the tiller buds to develop. Although tillering is affected by spacing, the capacity of sorghum varieties to tiller varies with varieties. Among the cultivated varieties, *S. durra* is normally non-tillering and Feterita belonging to *S. caudatum* is usually a tillering variety. Tillering connotes wild vigour and non-tillering condition is brought about by cultural and selective operations, until the whole plant puts forth its undeviated vigour into the production of one large earhead. The following experiences met with in Sudan grass help in understanding this valuable attribute of grasses, *viz.*, tillering.

Among the many *pure* lines of Sudan grass that are being grown at the Millets Breeding Station, S. 77 is one belonging to the collection from Guntur. This was true to the tillering habit in 1935. In 1936 the single plant selection carried forward from the 1935 crop, instead of coming pure as expected, segregated throwing out a few strange plants, anæmic, tillerless and absolutely single stalked (Fig. 7). There were 78 plants with tillers like the parent and 20 of the strange weak group. It was obvious that there had occurred a mutation heterozygous in nature. From this F<sub>2</sub>, an F<sub>3</sub> generation was raised and the behaviour of the selections is given below :

TABLE

Selection Number	Character of the F <sub>2</sub> Selection	F <sub>3</sub> Behaviour	
		Tillering	Single-stalked
S. 103	Single-stalked .. ..	..	Pure
S. 105	Tillering .. ..	Pure	..
S. 103	„ .. ..	Pure	..
S. 104	„ .. ..	49	14
S. 106	„ .. ..	70	26
S. 107	„ .. ..	96	32
S. 109	„ .. ..	134	48
	TOTAL .. ..	349	120
	Calculated 3 : 1 .. ..	351.75	117.25

$$X^2 = 0.086 \quad P > .7$$

It will be noted that 4 of the 6 tillering plants were heterozygous and segregated again. It is clear that the tillering habit is a monogenic dominant to the absolutely single-stalked non-tillering condition which has been met with for the first time in this sorghum. Out of the 120 single-stalked plants only 8 survived till maturity, the rest succumbing to the attack of the shoot borer. In the pure line S. 103, out of the 17 seedlings that germinated only one reached the stage of maturity. Being weak, the main shoot dying, and unable to produce tillers (basal buds absent), these anæmic plants are of very poor survival value. Before discussing this phenomenon, the contrasting characters in the two groups, *viz.*, tillering and absolutely single-stalked, are given below :—

Character	Tillering plants	Single-stalked plants
Tillers .. ..	12 to 15	Nil (basal buds absent)
Vigour .. ..	Healthy	Sickly
Seed-setting .. ..	Good	Poor (10 to 15%)
Panicle—		
Shape .. ..	Loose and conical	Compressed and rod-like (Fig. 8)
Top .. ..	Normal	Ending in a spur
Number of whorls .. ..	16 to 18	10 to 12
Pulvinus .. ..	Present	Absent
Primary branches .. ..	About 55° to the axis	Adpressed to the axis
Spikelets and their distribution	Many, evenly distributed	Few, crowded at tips of branches (Fig. 9)
Sessile spikelets—		
Number .. ..	1000 to 1200	Less than 200
Size .. ..	6.0 × 2.75 mm.	7.25 × 2.25 mm.
Sessile spikelets—		
Nature .. ..	Coriaceous and short-nerved	Papery and long-nerved
Length of nerves on glumes .. ..	2.5 mm.	5.5 mm.
Pedicelled spikelets—		
Number .. ..	1300 to 1500	Less than 50
Size .. ..	5.0 × 1.25 mm.	Mere scales or absent
Length of pedicel .. ..	2.0 mm.	Do.
Flowering .. ..	Ordinary	Partly cleistogamous

All these connote a primitiveness of equipment in the single stalked plant that has naturally not helped in the survival of this type in nature: The ready susceptibility to attack from the seedling-borer and the poor setting of seed make it difficult to perpetuate the single-stalked pure line.

With the help of this experience it has now become possible to give a genic background to this common phenomenon of tillering. A gene designated TX is at the back of the tillering habit in *S. sudanense*. Gene tx gives rise to an absolutely single-stalked (tiller-less) plant. The capacity to produce tillers is absent through the absence of buds at ground level. This is different from the single stalk of the grain sorghum in which the buds are present and could be activated. The higher axillary



leaf-buds could however be stimulated into activity, but since the frame of the plant is so frail this potentiality leads to no fruitful result. The spur that plumes the panicle seems to be the long central axis prolonged. The tillering habit, short coreaceous glumes, short nerves on these and the presence of pedicelled spikelets—attributes of modern sorghums—show the great advance in their evolution.

Whereas the above experience chronicles a case of tiller *versus* no tiller, Sudan grass has afforded a second interesting experience in the nature of advance in the tillering habit. Among the pure lines of Sudan grass there exist two distinct tillering types. The majority of pure lines have the first shoot well ahead of the later straggling tillers. In a few types the tillers flower practically along with the main stalk. At the flowering time the two types are very readily distinguishable, the latter being weak. In crosses between these two types the comparatively un-uniform flowering type proved a simple dominant to the dead uniform flowering type. In family No. S. 200, also from Guntur, there occurred a segregation giving 64 plants with tillers maturing much later than the main head and 22 plants with tillers maturing almost with the main head. The latter are shorter, their stalks are thinner, and the panicles are smaller, and there are no late tillers. It looks therefore that the lack of vigour in this group has been brought about by the over rapid activation of buds and the unspaced development of tillers arising from such activation.

A gene TU seems to be responsible for a gradual activation and delayed and spaced growth of tillers in Sudan grass. Gene tu gives rise to a uniform activation, uniform growth and maturity and consequent weakness of the tillers and the plant in general. These experiences in the tillering habit of Sudan grass are valuable in giving a clue to the fact that behind the vigorous tillering and the suppression of such tillers resulting in the single-stalked condition of Sorghum—the Great Millet—there exist genetic factors whose detection is difficult, under the obscuring effects of continued cultivation.

*Weak Midrib.*—Another phenomenon of great evolutionary interest is the weak midrib. In a family raised from selection S. 92 received from Trivandrum, which must have been a mutant (heterozygous), there occurred a number of plants very abnormal in appearance. In them, instead of the characteristic rigid leaves, the leaves were ribbon-like, weak, supple and bent down. Counts taken showed that there were 36 normal plants with a normal midrib in the leaves and 10 plants with a weak midrib. The weak-midrib-plants had many disabilities with the result that they did not produce

any seed. The occurrence of this rare character necessitated a large number of selections being carried forward to the third generation. Out of the 36 normal plants available, except the two that were very poor, all the others were carried forward and a third generation raised. Of the 34 selections, 11 were pure for normal plants and 23 segregated repeating the  $F_2$  experience. The figures are given below :—

TABLE  
*F<sub>3</sub> from S. 92 Family*

Selection Number	Character of Selection	$F_3$ Behaviour Midrib	
		Normal	Weak
S. 118	Normal Midrib ..	27	9
119	.. ..	24	9
120	.. ..	70	22
121	.. ..	46	13
122	.. ..	119	34
123	.. ..	50	17
124	.. ..	59	23
125	.. ..	106	33
126	.. ..	174	54
128	.. ..	57	19
131	.. ..	153	52
132	.. ..	67	22
133	.. ..	172	55
134	.. ..	17	4
135	.. ..	85	28

Selection Number	Character of Selection	F <sub>3</sub> Behaviour Midrib	
		Normal	Weak
S. 136	Normal Midrib ..	141	50
137	„ ..	107	34
138	„ ..	42	11
141	„ ..	41	13
142	„ ..	33	11
144	„ ..	74	26
147	„ ..	69	29
149	„ ..	122	46
	TOTAL ..	1855	614
	Calculated 3 : 1 ..	1851.75	617.25

$$X^2 = 0.023 \quad P < .8$$

A gene designated MD is responsible for producing a strong and normal midrib in the leaf-blade of sorghum. Gene md results in a weak midrib, which is the cause of the ribbon-like leaf-blades that lack erectness (Fig. 10).

Among the families which segregated and gave the weak-midrib there was also a segregation for the bluish-green<sup>s</sup> and green colour of (seedling) leaves in 14 of them. The cross-collated tabulation given below shows that the factor MD is independent of the factor C<sub>BL</sub> :

TABLE

Selection Number	Strong Midrib		Weak Midrib	
	Bluish-green	Green	Bluish-green	Green
S. 118 .. ..	19	8	8	1
119 .. ..	17	7	6	3
120 .. ..	53	17	17	5
122 .. ..	97	22	27	7
125 .. ..	86	20	27	6
126 .. ..	135	39	39	15
128 .. ..	47	10	13	6
132 .. ..	55	12	18	4
133 .. ..	130	42	36	19
134 .. ..	12	5	2	2
135 .. ..	64	21	20	8
144 .. ..	57	17	19	7
147 .. ..	49	20	23	6
149 .. ..	97	25	33	13
TOTAL (actual) ..	918	265	288	102
Calculated (9 : 3 : 3 : 1) ..	884.7	294.9	294.9	98.3

$$X^2 = 4.58 \quad P > .20$$

The weak-midrib is weak up to 5 cm. from the top of the leaf-sheath after which it loses its individuality and becomes like one of the nerves in the blades (Fig. 11). Even this trace of the midrib is lost in the top leaves and the flag is midribless. Detailed measurements taken in 10 plants in each of the groups, normal and weak-midribs, show that in height of plants, thickness of internodes, number of leaves, length and breadth of leaf-blades,

duration and in general panicle shape, both the groups are alike. Besides the weakness in the midrib, the only difference is a distinct pull-down in the tillering capacity which is inevitable owing to the disability imposed upon the photosynthetic equipment. In the normal plants the thickness of the midrib of the fourth leaf from the top is 2.0 mm. at the base, 1.2 mm. at the middle and 0.027 mm. at the top which is the same as the thickness of the blade. In the case of the same leaf with the weak-midrib it is 0.7 mm. at the base, 0.5 mm. at the middle, and 0.27 mm. at the top. These measurements explain the drooping down of the ribbon-like leaves.

The consequences attendant on the presence of the weak-midrib are of still greater interest. Owing to the rarity of this occurrence, practically every plant with a weak midrib was carefully examined in all its parts. Along with the suppression of the midrib there is a suppression of the style and stigma (Fig. 12). In most cases these organs are completely absent and in stray cases vestiges of the style are present. Concurrent with the suppression of the style and stigmatic tissue there is a suppression of the tissue of the awn. Whether the spikelets are 'nil'-awned or long-awned the normal lemma is distinctly bifid, with a strong awn-base which protrudes only a short distance if it is 'nil'-awned (Fig. 13) or to a greater distance if it is long-awned (Fig. 14). In the weak-midribbed plants when the style and stigma are completely absent, the lemma is entire (bifid nature not seen) (Fig. 15) and there is no specialised tissue connoting the awn-base. When occasionally the vestiges of the styles are present, there is concurrently a faint manifestation of the awn-base (Fig. 16).

The genetics of the awn has been worked out and the 'nil'-awned condition (extreme reduction in length) is dominant to the long-awned condition. In a dihybrid segregation from normal and weak-midrib, and 'nil'- and long-awned condition instead of the theoretical 9 : 3 : 3 : 1 ratio, there occurred a 9 : 3 : 4 ratio as will be seen from the following table.

TABLE

Selection Number	Normal-midrib		Weak-midrib	
	'Nil'-awn	Long-awn (9-11 mm.)	'Nil'-awn	Long-awn (9-11 mm.)
S. 118 .. .. .	18	9	9	..
122 .. .. .	89	30	34	..
124 .. .. .	43	16	23	..
125 .. .. .	77	29	33	..
126 .. .. .	134	40	54	..
128 .. .. .	39	18	19	..
132 .. .. .	46	21	22	..
133 .. .. .	128	44	55	..
135 .. .. .	63	22	28	..
137 .. .. .	84	23	34	..
141 .. .. .	29	12	13	..
144 .. .. .	57	17	26	..
TOTAL (actual) ..	807	281	350	..
Calculated (9 : 3 : 4) ..	809.1	269.7	359.6	..

$$X^2 = 0.74 \quad P > 0.50$$

The awn segregation in the weak-midrib plants is not felt, due to the lack of awn tissue (homologous to the midrib). Gene *md* which affects the midrib affects also the homologous awn tissue. The very intimate connection between the midrib and the awn easily explains this phenomenon. It has been shown, that when the leaf-blade is forked, the awns are forked likewise.<sup>25</sup> When a severe attack of *Sclerospora* occurred and affected the leaf-blade, there was a suppression of the awn.<sup>26</sup> The effect of the weak-midribbed condition does not stop with this concurrent effect on the

leaf-blade and the awn, but also extends to the style and stigma. The homology between stigma and awn in sorghum has been given in great detail in a number of publications.<sup>13, 27, 28, 29</sup> Gene *md* affects the style and stigma vitally and they are entirely absent or only the rudiments of the style are present.

This accounts for the non-setting of seed in the flowers of the weak-midribbed plants, though the earhead is normal and the anthers emerge quite normally. The other effects of this weak-midribbed condition are the occasional presence of a fully developed dorsal lodicule<sup>30</sup> and in stray cases a second set of three anthers.

These experiences are of very great interest in the evolution of plant organs. The homology between the leaf-blade and awn, and between style and stigma and the column and subule of the awn has been well established. This experience in Sudan grass threads up all the three homologous organs, *viz.*, midrib, awn and stigma. A serious disturbance in vegetative equipment produced catastrophic effects on the homologous reproductive equipment.<sup>31</sup> Such abnormal characters, resulting in sterility, could be produced by X-ray treatment, but their occurrence in nature is possibly to be explained through mutation induced in a new environment.

Coming to grain sorghums an instance is on record in which a cross between *S. durra* of Coimbatore and *S. nigricans* of Tanganyika (with pedicelled spikelets fertile)<sup>32</sup> gave in the  $F_2$  a few plants whose side-shoots showed midribless leaves. Another interesting experience is worth recording here. Bulbils in earheads are a rare occurrence.<sup>33</sup> One such bulbil was nursed till it produced an earhead. In that plant of abnormal origin two leaves had no midribs. The first seedling-leaves in all sorghums do not elaborate a midrib.<sup>20</sup>

These interesting experiences are useful in throwing helpful light in the evolution of the Gramineæ, their leaf-sheath, leaf-blade and ligular and auricular equipment, glume and awn structures, lodicular, stylar and stigmatic elaborations, and help us to appreciate the big advance they have made in having their present equipment which has helped them to become the premier group among crop plants.

#### *Summary*

An agro-botanical description of the Sudan grass (*S. sudanense*, Stapf) is given and the many affinities to cultivated sorghums are mentioned. Sudan grass is believed to have contributed to the origin of the cultivated sorghum *S. dochna*. The rare and simple recessive characters, *viz.*, *e*-ligulate

leaves and compact-spindle panicles and the rare dominant character, purple-washed pedicelled spikelets (gene PW) occur in both *S. sudanense* and in *S. dochna*. Besides these, characters experienced only in Sudan grass so far, are also described. Seedlings with banded chlorophyll deficient areas have been met with. This character has proved a simple recessive to the normal whole green. A gene *cb* is responsible for this character. There are two types of seedling habits, *viz.*, open and erect. The former is a simple dominant to the latter and the gene *SO* is behind this character. Rare types with faint longitudinal stripes on leaves have occurred and have proved a simple recessive (gene *cs*) to the normal non-striped condition (gene *CS*). There is a great pull down in the waxy bloom condition in this grass. Even in this poverty of manifestation the very sparse condition (on leaf-sheath and internode) is a simple dominant to the extremely sparse condition (traces on the boot only). The gene controlling the angle which the primary branches make with the central stalk of the panicle does not determine a similar disposition of the secondary branches to the primary one. A new gene *Pa<sub>2</sub>* makes the secondary branches pulvinate and divergent to the primary branch. Gene *pa<sub>2</sub>* results in the absence of the pulvinus in the secondary branches (and consequently the secondary branches are adpressed to the primary branch). The Sudan grass has thrown light on the evolution and arrangement of the spikelets in sorghum in general, as the spikelets are sparse. The spikelets are arranged in a dichasial cyme with an alternate development. The sessile spikelets represent the older ones and explain the two waves of anthesis in sorghum. A proliferated earhead in which the lower panicle branches turned foliate is recorded. Cereals, which are also grasses, tiller. Tillering is an aspect of vigour. In Sudan grass the gene responsible for tillering *TX* could be isolated and is a simple monogenic dominant to the non-tillering condition *tx*. Gene *tx* produces weak single-stalked plants in which the basal and underground axillary buds are absent. Their panicles are weak, spurred and rod-like, and the spikelets are few and cluster at the terminals. The glumes are long, papery and develop long nerves. The pedicelled spikelets are practically absent being reduced to mere scales. The plants do not survive the shoot-borer attack and this is due to the inability to produce tillers in replacement of the main shoot. Gene *tx* has however no effect on the higher axillary buds. Next to the tiller-less single-stalked condition is the uniform tillering habit. Gene *tu* is responsible for this. Though many tillered, their gush of growth (want of a slow spaced development induced by gene *TU*) results in exhaustion and consequent weakness. *TU* is a simple monogenic dominant to *tu*. A strong midrib is an essential equipment in the long



leaf-blades in grasses, especially in cereals. Gene MD produces the normal strong midrib. Gene md results in a weak-midrib that makes the leaf ribbon-like and droop down. The midrib being homologous to the awn and stigma, there is a concurrent suppression of the awn and of the stylar and stigmatic organs. Gene MD has been found to be independent of gene C<sub>BL</sub>, which produces bluish-green seedling leaves.

LITERATURE CITED

1. Snowden, J. D. . . . *The Cultivated Races of Sorghum*, 1936.
2. Rangaswami Ayyangar, *Curr. Sci.*, 1937, 5, 538-39.  
G. N., et al.
3. —————, et al. . . . *Ibid.*, 1936, 5, 299-300.
4. ————— and Ponnaiya, B. W. X. *Ibid.*, 1937, 6, 158.
5. ————— . . . *Agric. J. Ind.*, 1930, 25, 262-63.
6. —————, et al. . . . *Curr. Sci.*, 1938, 6, 556-57.
7. —————, et al. . . . *Ind. J. Agric. Sci.*, 1933, 3, 589-94.
8. ————— . . . *Madras Agric. J.*, 1934, 22, 1-11.
9. ————— . . . *Ibid.*, 1935, 23, 350-52.
10. —————, et al. . . . *Ind. J. Agric. Sci.*, 1933, 3, 605-08.
11. —————, et al. . . . *Proc. Ind. Acad. Sci.*, 1938, 7, 161-76.
12. —————, et al. . . . *Ibid.*, 1937, 5, 4-15.
13. ————— and Rao, V. P. *Curr. Sci.*, 1935, 3, 540-42.
14. —————, et al. . . . *Ind. J. Agric. Sci.*, 1935, 5, 539-41.
15. —————, et al. . . . *Proc. Ind. Acad. Sci.*, 1938, 7, 286-88.
16. ————— and Ayyar, M. A. S. *Ibid.*, 1938, 8, 100-07.
17. ————— and Ponnaiya, B. W. X. *Curr. Sci.*, 1937, 5, 590.
18. —————, et al. . . . *Ibid.*, 1938, 6, 612-13.
19. —————, et al. . . . *Proc. Ind. Acad. Sci.*, 1938, 8, 317-23.
20. —————, et al. . . . *Ibid.*, 1938, 8, 151-56.
21. Cherian, M. C., and Kailasam, M. S. *Proc. Assoc. Econ. Biologists*, 1936, 1-7.
22. Rangaswami Ayyangar, G. N., and Ayyar, M. A. S. *Madras Agric. J.*, 1934, 22, 407-08.
23. Favorov, A. M., and Havenselman, P. S. *Herb. Rev.*, 1934, 2, 143-47.

254 G. N. Rangaswami Ayyangar and B. W. X. Ponnaiya

24. Rangaswami Ayyangar, *Indian J. Agric. Sci.*, 1931, 1, 445-54.  
G. N., and Rao, V. P.
25. —————, *et al.* .. *Curr. Sci.*, 1935, 4, 316-17.
26. ——— and Hariharan, *Ibid.*, 1935, 3, 363-64.  
P. V.
27. ——— and Rao, V. P. *Ibid.*, 1935, 4, 176-77.
28. ——— and Reddy, T. V. *Ibid.*, 1936, 4, 817-20.
29. ————— .. *Madras Agric. J.*, 1938, 26, 123-26.
30. Long, B. .. *Bot. Gaz.*, 1930, 89, 154-68.
31. Anderson, E., and De Winton, D. *Annals of Bot.*, 1935, 49, 671-88.
32. Rangaswami Ayyangar, *Curr. Sci.*, 1935, 3, 433-34.  
G. N., and Rao, V. P.
33. ————— .. *Ibid.*, 1935, 3, 362-63.

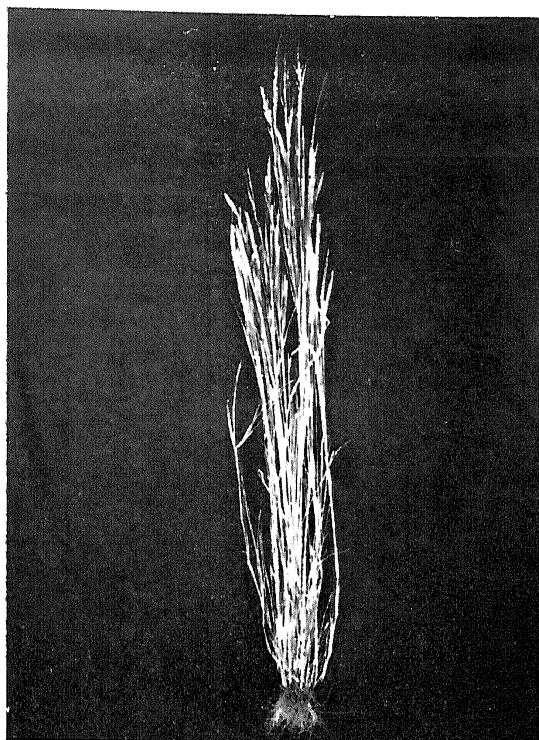


FIG. 1  
E-ligulate Plant

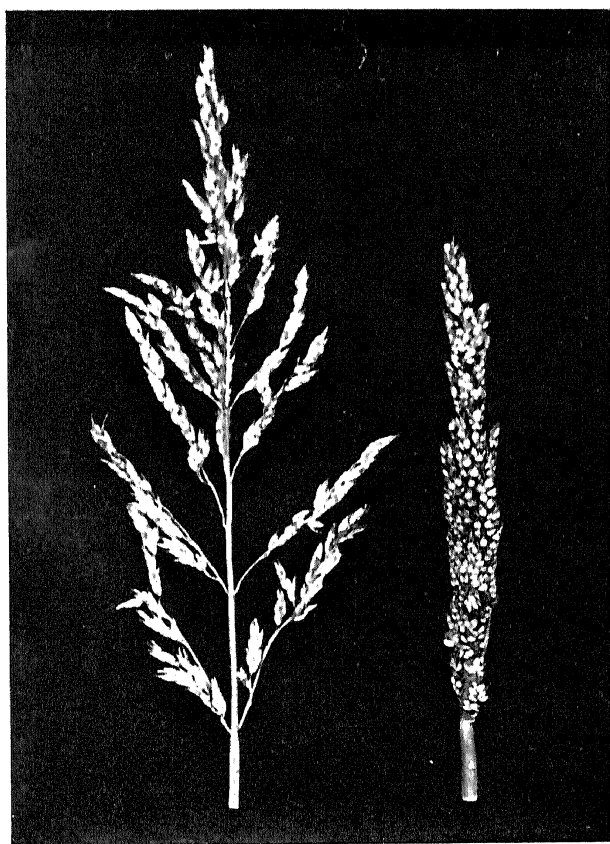


FIG. 2  
Ligulate Panicles  
E-ligulate

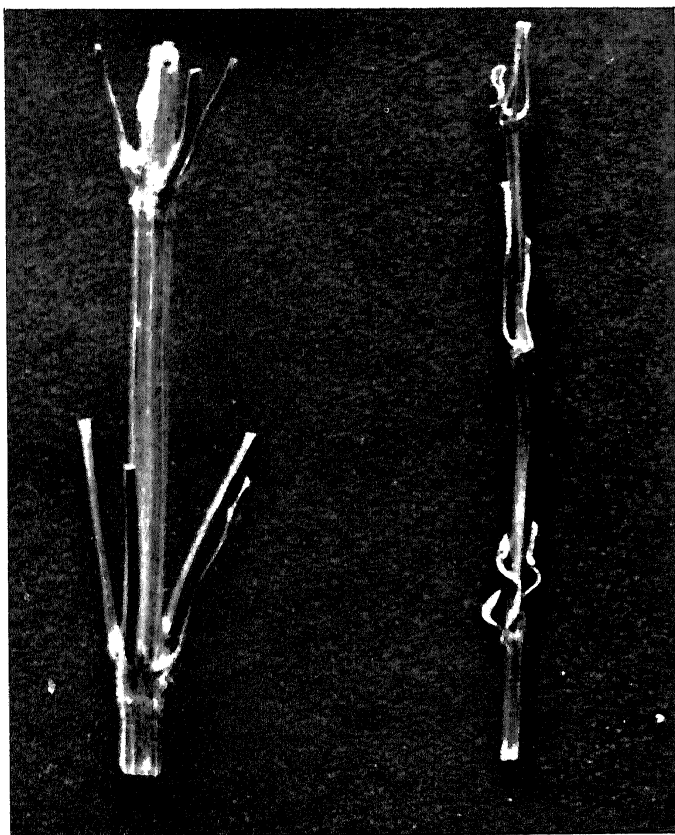


FIG. 3  
Ligulate Pulvinate  
E-ligulate Non-pulvinate  
Central Axis of Panicles

E-ligulate Plant of Sudan Grass

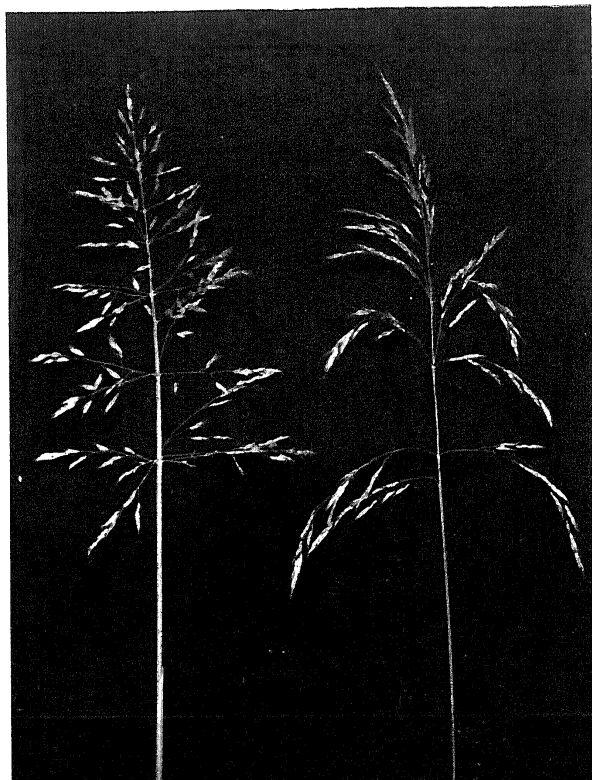


FIG. 4

Divergent

Adpressed

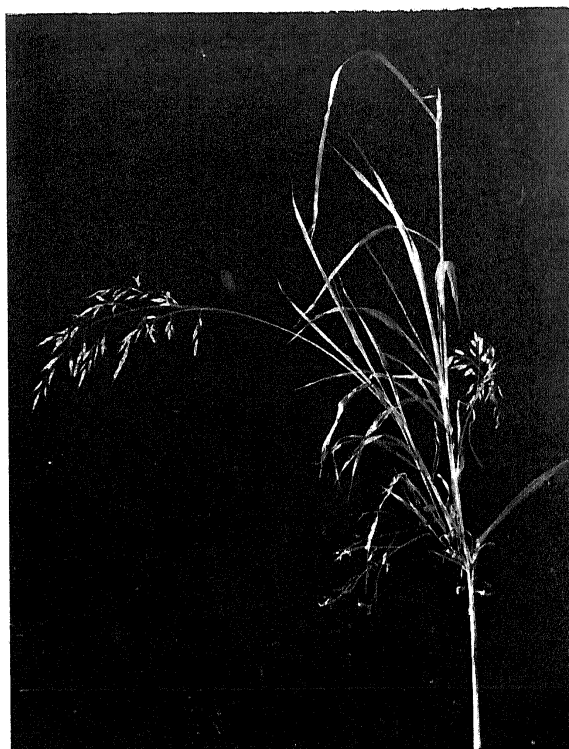


FIG. 5

Panicle—lower branches turning foliate



FIG. 6

Arrangement of Sessile and Pedicelled Spikelets

Panicle of Sudan Grass



FIG. 7  
Whole Plants

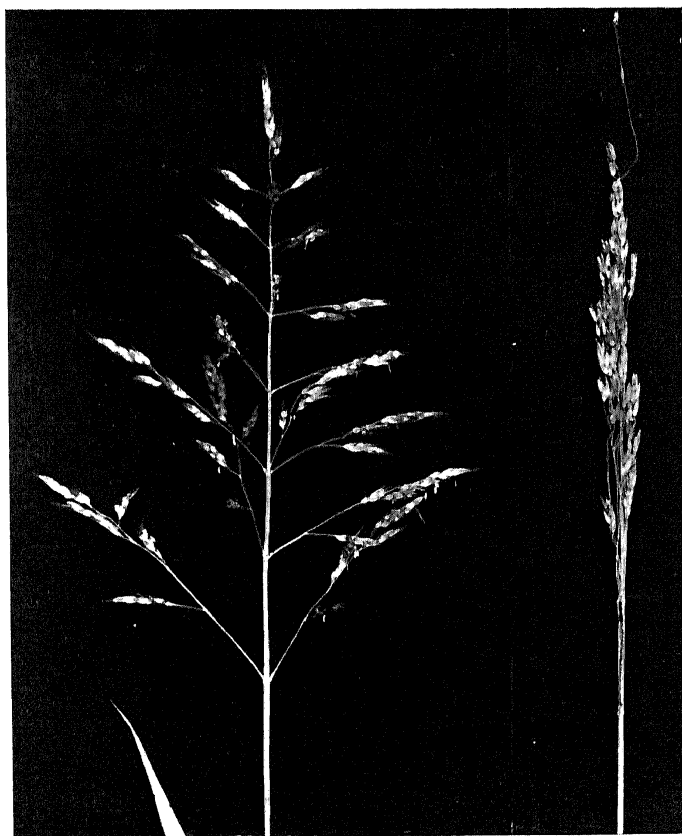


FIG. 8  
Panicles

← Spur

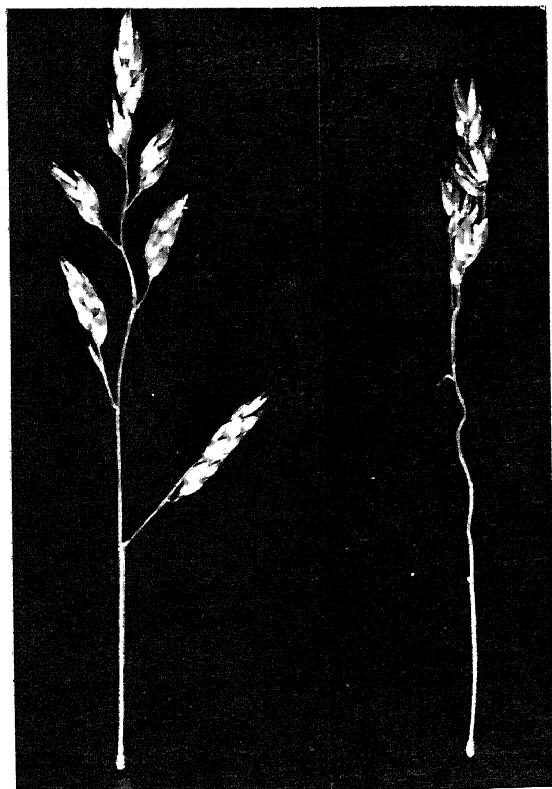


FIG. 9  
Panicle Branches



FIG. 10. Whole Plants

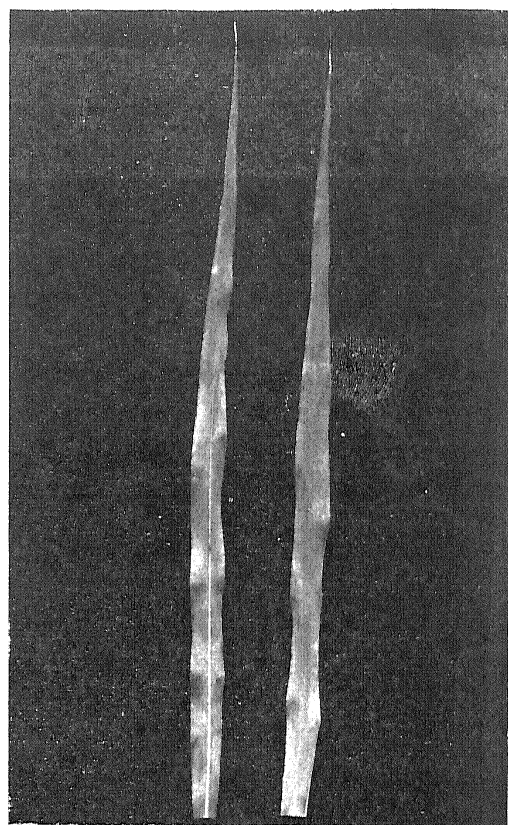


FIG. 11. Leaves

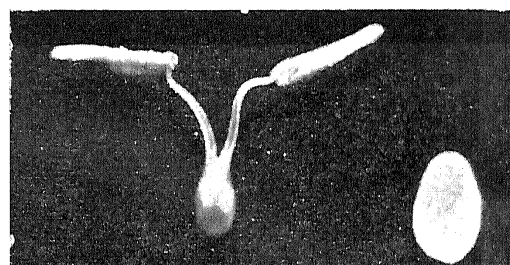


FIG. 12. Ovaries

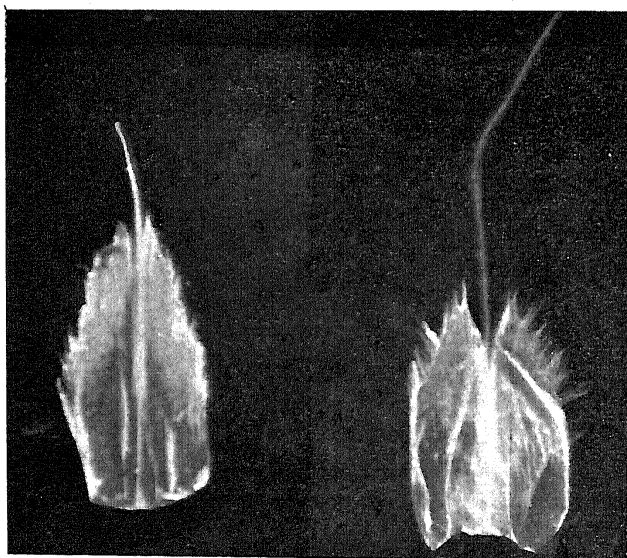


FIG. 13  
'Nil'-awn  
Top of lemmas—lobed  
Lemmas—from Normal midribbed plants

FIG. 14  
Long-awn  
Fully lobed

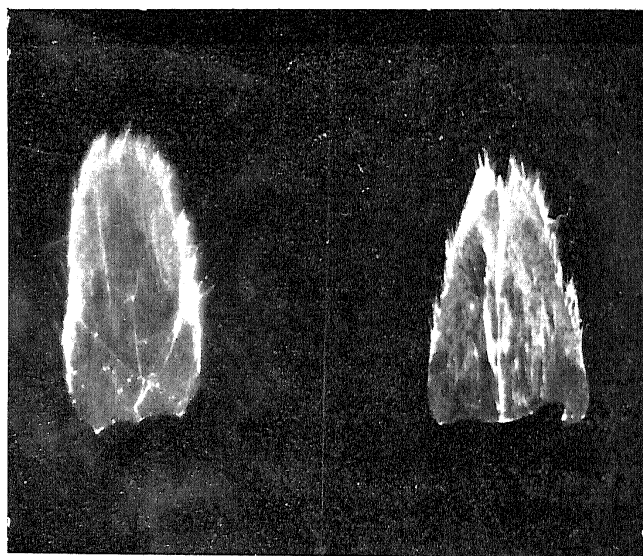


FIG. 15  
No awn traces  
No lobes

FIG. 16  
Faint awn base  
Feebly lobed  
From Weak midribbed plants