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Some Observations on Mendelian Characters in Sorghum.

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The material that has been made use of in the preparation of this note was gathered mostly from the Irungu and Tellajonna varieties grown at the Hagari Agricultural Station during the years 1916-1920.

Pollination. As described by R. J. D. Graham in his "Pollination and cross fertilization in the Juar plant"[1], there are a sessile and one or two pedicelled spikelets on the branches of the panicle. The former is hermaphrodite, while the latter is generally sterile, and if functional, staminate. Unlike the case in ordinary racemes, the top-most flower is the first to open. The time the flower opens depends on atmospheric conditions. When the temperature is high during the nights, the spikelets commence opening at about 1 A. M. When the nights are chill the opening is delayed even up to 8 A. M. On 12-12-1918 when the morning was chill, the glumes opened at about 7-30 A. M. But on the next day, 13-12-1918, when the sky was overcast with clouds the flowers in the same type opened between 5 and 6 A. M. Stray flowers were often observed to open as late as 4 P. M. It was noted that the anthers in the flowers more exposed to the light emerged earlier than those on the shady side. There is also some variation in the time of opening in different varieties. Irungu cholam opens earlier than Chinna manjal. This in turn is earlier than Patcha jonna and Patcha has been found to be earlier than Narival cholam, during the months of December and January when this observation was made. In the

1. Graham, R. J. D. Mem. Dept of Agri. in India, Bot. Series, Vol. viii, No 4.

Irungu varieties, the feathery stigmas emerge first, pushing out the stamens to the sides. The filaments grow very rapidly, and the anthers hang out and then dehisce. The elongation of the filaments and the bursting of the anthers is completed in 2 to 3 minutes. In certain varieties like Tella jonna where the heads are exceedingly compact, the tip of the stigma can be identified, even 36 hours before the appearance of the stamens. The stigma is then neither dilated nor receptive.

The anthers rarely protrude, but remain in their places and dehisce. The sequence in bursting and the pendent position of the anthers clearly signify that nature has meant this arrangement to effect cross pollination of the lower flowers. It may also be noted here, that it takes about 6 to 7 nights for the complete pollination of all flowers in a head. The topmost flower of the lower tier opens simultaneously with the flowers at the base of the upper tier so that the pollen dust from the upper rows will scarcely miss the stigmas of the lower flowers.

When the pedicelled spikelets are functional, these commence to exsert their anthers when the main flowering has advanced to the middle of the head. This double system of pollination occurs, as far as the writer's observation goes, only in loose panicles. The glumes remain open for about three to four hours and gradually close leaving the stigma at the angles. These begin to fade at about 2 P. M. The anthers are either pale or deep yellow at the time of emergence but turn pale or deep brown, on fading.

Frequency of cross pollination. The two facts, that sorghum flowers are protogynous, and that an entire head takes a week to get pollinated, make the sorghum susceptible to foreign pollination. The following table gives the extent of cross pollination observed in certain characters.

Table I.

Reference No.	Character that was observed.	Percentage of cross pollination.
26	No hairs	13 per cent
75	do.	1 ,,
80	do.	3 ,,
230	do.	14 ,,
237	do.	35 ,,
80	Black	8 ,,
97	do.	8 ,,
45	do.	6 ,,
237	Long awns	10 ,,

Method of selfing. The above figures will testify to the necessity of selfing. Any device to prevent foreign pollination in Sorghum must be operative for about 10 days, and should be so designed as to provide for the rapid elongation of the last internode. When bags are left on the plants without any standard, the lower branches of the panicle often escape selfing, due to the frequent tossing about of the plants by the wind. The device which has proved most satisfactory is to plant 3 bamboos around the plant to form a tripod, and to fasten the corners of the bag to the bamboos. The noose at the mouth has to be tightened so as to leave no hole. Every morning the bag has to be moved up the bamboos, in proportion to the elongation of the last internode.

(*1*) *Hairs on the glumes.*

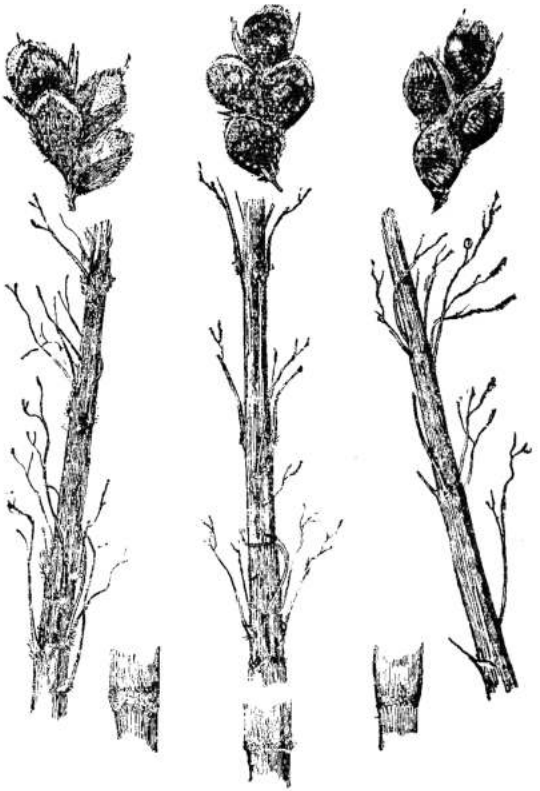
The hairs referred to in this para are borne on the outermost glume enclosing the grain. In the "many hairs" type, there is a dense felt on the outer surface. This is easily distinguished by the eye, even when the heads just protrude from the sheath. As the panicles grow old, the hairs are liable to be brushed off. But it is possible in most cases to sort them out as "many hairs", as several hairs will still be present on the glumes. Besides it was discovered that the band above the node is densely clothed with a belt of hairs, which serves as a sure guidance to mark out the hairy plant, long before it throws out its head. Also the rachis especially at the 1st and 2nd node, is pubescent. (vide Plate I).

In the case of "no hairs" plant, the declaration cannot be done so easily. In some of the plants, hairs are observed only at the shoulders, whilst in others it forms an arc from shoulder to shoulder with an odd hair or two over the convex surface of the glume, and in another lot the whole glume appears glabrous to the naked eye, but shows a few hairs if examined under a lens or a dissecting microscope. The "no hairs" of one selection may when compared with "no hairs" of another selection, appear different. Thus selection No. 290 when compared with selection No. 218 bears more hairs on the glumes with a corresponding increase in the number of hairs at the joints of the rachis, although both of them are classed "no hairs". In all these plants the ring of hairs is practically absent on the band above the node, and only a few hairs are discernible at the first and second nodes of the panicle.

In spite of this wide variation, the "no hairs" behaves as a simple recessive segregating into 3:1 ratio.

N. B:—Figures given in the last column represent the pure and impure plants found in that plot.

PLATE I. (Vide page 3.)



Many Hairs. Few hairs 'No hairs'

Table II.

Year.	Origin.	Reference.	Character of the parent.	Many hairs.	No. hairs.	Remarks.
1916-17.	Pavala Sevappu (Irungu)	1	...	74	26	This count was made by Mr. Hilson.
1917-18.	1	25	...	122	48	*
,,	,,	26	...	...	Mostly	(170.25) *

,,	,,	27		...	...	All	(223)	*
,,	,,	28		...	61	19		*
,,	,,	29		...	322	108		*
,,	,,	30		...	All	...	(259)	*
,,	,,	31		...	...	Mostly	(391.2)	*
,,	,,	32		...	All	...	(456)	*
,,	2	33		...	...	All	(67)	
,,	,,	34		...	...	All	(157)	
,,	,,	35		...	...	All	(800)	
,,	,,	36		...	...	All	(404)	
,,	,,	37		...	...	All	(461)	
,,	,,	38		...	...	All	(642)	
,,	,,	39		...	...	All	(519)	
,,	,,	40		...	197	58		
,,	3	44		...	556	200		
,,	,,	49		...	62	31		
1918-19	25	72	N	No hairs	...	All	(306)	
,,	,,	73	S	No hairs	...	All	(179)	
,,	,,	74	S	No hairs	...	All	(340)	
,,	,,	75	N	No hairs	...	Mostly	(877.7)	
,,	,,	76	N	No hairs	...	All	(516)	
,,	,,	77	N	Many hairs	102	27		
,,	,,	65	N	No hairs	...	All		*
,,	,,	66	N	No hairs	...	Mostly		*
,,	26	78	S	No hairs	...			
From the natural crosses.						All	(97)	
,,	,,	79	S	Many hairs	260	82		
,,	,,	80	N	No hairs	...	Mostly	(570.14)	
,,	,,	82	N	No hairs	...	Mostly		
,,	,,	83	N	Many hairs	264	110		
,,	28	84	N	No hairs		All	(427)	
,,	,,	85	S	Many hairs	291	82		
,,	,,	87(a)	S	Many hairs	406	118		
,,	,,	88(a)	S	Many hairs	All		(557)	
,,	,,	89(a)	S	Many hairs	233	61		
,,	30	90	N	No hairs	...	All		
,,	,,	93	S	No hairs	...	All	(99)	
,,	28	86	S	Many hairs	184	71		
1918-19	30	94	S	Many hairs	All	...	(321)	
,,	,,	95	S	,,	107	31		
,,	,,	96	N & S	,,	All	...		
,,	31	97	N	,,	264	103		
,,	Natural	98	N	,,	383	136		
,,	Crosses							

Year.	Orign.	Reference.	Character of the parent.	Many hairs.	No hairs	Remarks.	
,,	Do 32	99 N	,,	195	96		
,,	,,	100 N	,,	152	66		
,,	,,	101 N	,,	149	82		
,,	,,	102 N	,,	122	19		
,,	,,	103 N	,,	599	391		
,,	40	115 N	No hairs		All	(268)	
,,	,,	116 N	Many hairs	All		(912)	
,,	21	60 S	,,	922	275		*
,,	,,	61 S	,,	440	134		*
,,	,,	62 S	No hairs	...	Mostly	(370.1)	*
,,	,,	63 S	Many hairs	355	115		*
,,	,,	64 S	,,	486	155		*
1919-20	94	226 S	,,	All	...		
,,	99	228 S	No hairs	...	Mostly	(301.4)	
,,	,,	230 N	,,	...	Mostly	(147.21)	
,,	,,	248 S	,,	All	...	(195)	
,,	,,	249 S	Many hairs	123	67		
,,	,,	250	,,	All		(55)	
,,	100	232 S	No hairs	...	Mostly	(219.10)	
,,	,,	251 S	Many hairs	37	65		
,,	,,	252 S	,,	29	22		
,,	101	234 S	,,	107	24		
,,	,,	235 S	,,	125	51		
,,	,,	237 N	No hairs		Largely	(146.76)	
,,	102	242 S	Many hairs	All	...	(410)	
,,	103	246 S	,,	All	...	(113)	
,,	60	215 S	,,	170	61		
,,	,,	216 S	,,	All			
,,	61	217 S	,,	128	39		
,,	,,	218 S	No hairs	...	All		
,,	62	219 S	,,	...	All		
			Total...	8027	2973		
			Expectation (3:1)	8250	2750		

* Counts in these selections were taken conjointly by Mr, Hilson and the writer.

In 1919 selections 99, 100, 101, 102 and 103 were sorted out after examining the heads under a dissecting microscope. Those that exhibited an odd hair or two on the glumes, or that appeared glabrous

were designated as "no hairs." Such of the plants as were not clothed with hairs on the entire surface were thrown into the "few hairs" lot. The counts according to this arrangement were:—

Table III.

Reference.	Character of the parent	Many hairs.	Few hairs.	No hairs.
99 N	Many hairs	195	79	17
100 N	Many hairs	152	57	9
101 N	Many hairs	149	66	16
102 N	Many hairs	122	19	....
103 N	Many hairs	599	338	53
		1217	559	95

This ratio may call to the mind that the many haired plant is a resultant of two pairs of allelomorphs. But in that case the ratio between "many hairs" and the "no hairs" in Table II should be 9: 7 as "no hairs" include also "few hairs". The next progeny from these plants were not examined for this point and no further inference can be drawn.

(2) Colour of the Glumes.

The Irungu varieties are generally named according to the color of the glumes. *Pavala Sevappu* (coral red), *Kanmudi Sevappu* (light red), *Sevappu Mapillai Miniḳi* (red and shiny), are some of the names given to red-glumed varieties to denote the various shades in color. If the glumes are black they go by the name of *Kaḳai cholam* (crow black). These colors develop gradually as the grains mature. During the milk stage the red and black glumes cannot be differentiated, as red is the prevailing color. When the grains have set well the various shades are clearly discernible. A number of factors may contribute to the production of the blends, as some of them breed true. There is no regularity either in the intensity or in the distribution of the pigment. Coloring is very often confined to a thin band at the base of the glume, which is taken advantage of in sorting. As the red is metamorphosed into black, an inhibitory factor must be responsible for the non-development of black color in all the glumes Black behaves as a pure recessive with regard to red in a simple 3: 1 ratio.

Table IV

Year.	Origin.	Reference.	Character of the parent.	Red.	Black.	Remarks.
	Pavala					This figure was
1916-17	Sevappu	1	...	55	21	obtained by
1917-18	1	25	...	103	73	Mr. Hilson.
,,	,,	26	...	153	45	
,,	,,	27	...	68	23	
,,	,,	28	...	50	8	
,,	,,	30	...	160	63	
,,	,,	31	...	275	73	
,,	,,	32	...	All	...	(456)
,,	2	33	...	...	All	(67)
,,	,,	34	...	All	...	(157)
,,	,,	35	...	...	All	(800)
,,	,,	36	...	274	82	
,,	,,	37	...	346	122	
,,	,,	38	...	457	185	
,,	,,	29	...	373	144	
,,	,,	40	...	179	62	
,,	,,	41	...	All	...	
,,	3	42	...	...	All	(278)
,,	,,	43	...	...	All	(363)
,,	,,	44	...	521	164	
,,	,,	45	...	...	Mostly	(263.16)
1918-19	26	78m S	Deep red	72	25	
,,	,,	79 S	Red banded	All	...	(342)
,,	,,	80 N	Black	...	Mostly	(584.52)
,,	,,	83 N	Red	303	71	
,,	28	84 N	Deep red	320	107	
,,	,,	85 S	Red	278	95	
,,	,,	86 S	Dark red	172	83	
,,	,,	88 S	Red	411	146	
,,	,,	89 S	Deep red	227	67	
,,	31	97 N	Black	...	Mostly	(336.31)
,,	,,	98 N	Light red	388	139	
,,	40	108 (a)S	Black	...	All	(442)
,,	,,	116 S	Deep brown	681	231	
,,	,,	115 N	Red	All	...	(268)
,,	T. 32	T. 37 N	Dark red	228	134	
,,	,,	T. 38 N	Dark red	214	68	
,,	,,	T. 39 N	Dark red	160	56	
			Total	6468	2287	
		Expectation (3:1)		6567	2189	

It may be mentioned here that in selections 36 and 39 the heads were classified according to the color of the band at the base of the glume, due to the non-development of the color over the glumes.

Another interesting character noted in type 29 was that there were neither bands nor any color noticeable on some of the heads. When counts were taken for the red-banded and the unpigmented, the numbers stood as 262: 89. As this charactor was not studied in the next progeny, nothing more can be said about this.

Again in selection 25 the ratio obtained between red and black was abnormal in 1917-18, the figures being 103: 73. When the next generation was studied for this character the numbers shown in Table IV were obtained. Whether they connote any Mendelian phenomenon or only aberrant forms was not investigated due to the pressure of other work.

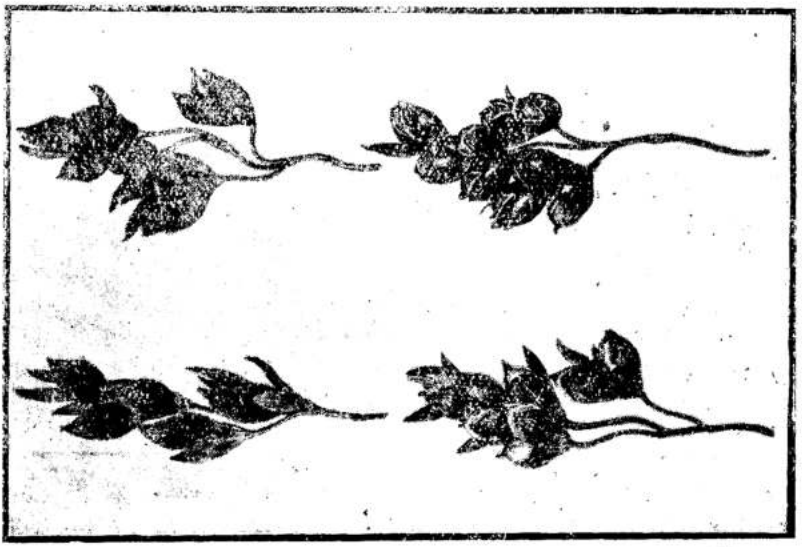
Table IV.

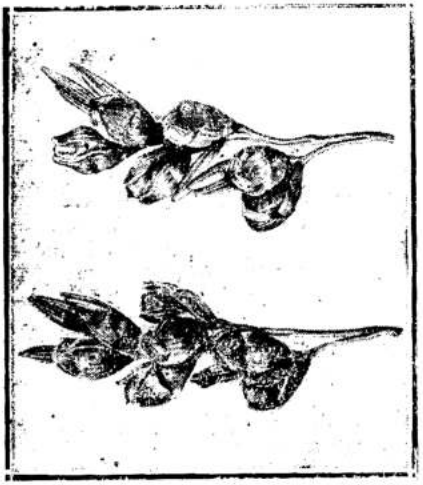
Year.	Origin.	Reference	Character of the parent.	Red.	Black.
1917-18.	1	25	...	103	73
1918-19.	25	72 N	Reddish black	126	280
...	...	73 S	Black	...	All(179)
...	...	74 S	Black	95	249
...	...	75 N	Dark red	521	1132
...	...	76 N	Deep brown	198	358
...	...	77 N	Black	48	75

(3) Red pigmentation on the apex of the glumes and over the pedicelled spikelets (Vide Plate II)

Whether these two are only manifestations of one unit character and a localisation factor determines the distribution of the pigment, could not be decided, as the counts were few and as they were not followed up further. At any rate the segregation is significant.

PLATE II[1/2] (Vide page 9)





Pigmentation on glumes and pedicelled spikelets.

Table V.

Year.	Origin.	Reference	Character of the parent.	Red apex.	Self color
1917-18	2	36	...	305	99
...	...	39	...	385	134
			Total	690	233
			Expectation (3:1)	696	232
			Red pedicelled spikelets.	non-pigmented pedicelled spikelets.	
...	4	58 Tiller (1)	30	19	
...	...	... (2)	53	25	
...	...	... (3)	352	131	
...	...	... (4)	775	210	
...	3	45	201	62	
		Total	1411	447	
		Expectation (3:1)	1393.5	464.5	

(4) Wrinkled glumes.

In 1918 in a pure crop of T. 32 there were some plants in which the grains were exposed and the glumes were wrinkled (Plate III). The seeds from these heads were sown in plots and counts were taken. Wrinkled behaved as a dominant.

Table VI.

Year.	Origin.	Reference.	Character of the parent.	Wrinkled.	Not Wrinkled.
1918–19	T. 32	36 N	Wrinkled.	391	133
,,	,,	37 N	do.	268	94
,,	,,	38 N	do.	205	77
,,	,,	39 N	do.	160	56
			Total	1024	360
			Expectation 3:1	1038	346

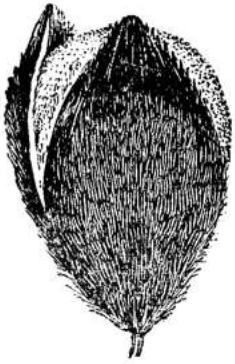
(5) Awns.

In 1918 in selection No. 32 six short awned plants were observed. These when sown in plots produced offspring bearing various grades of beards. The longest were easily spotted out. The others defied classification and hence were clubbed together as short awns to eliminate the error in grouping. The fully bearded bred true whilst in the "short awns" some bred true and some broke into long and short awns. The long awns behave as a recessive.

Table VII.

Year.	Origin.	Reference.	Character of the parent.	Short awned.	Long awned.
1918–19	32	99 N	Short	222	69
,,	,,	100 N	Short	162	66
,,	,,	101 N	Short	178	53
,,	,,	102 N	Short	116	24
,,	,,	103 N	Short	405	157
1919–20	99	227 S	Short	211	60
,,	,,	248 S	Short	147	48
,,	,,	250 S	Long	...	Almost (54.1)
,,	100	251 S	Short	All	(121)
,,	,,	232 S	Short	182	49
,,	,,	252 S	Long	...	All (51)
1919-20	101	234 S	Long	...	All (131)
,,	,,	235 S	short	All	...
,,	,,	236 S	Long	...	Mostly (184.19)
,,	,,	237 N	Long	...	Mostly (376.42)
,,	,,	253	Short	57	18
,,	102	238 S	Short	All	
,,	,,	239 S	Short	245	75
,,	,,	240 S	Short	384	107
,,	,,	241 S	Short	All	... (345)
,,	,,	242 S	Short	305	105
,,	103 a.	243 S	Long		All
,,	,,	244 S	Long		Mostly
,,	,,	245 S	Short	All	...
,,	,,	246 S	Short	399	95
,,	,,	247 N	Short	All	
		Total		3013	926
		Expectation (3 : 1)		2954	985

PLATE III. (Vide page 11)



Not Wrinkled.

Wrinkled.

(6) Close and open heads.

There is a huge variation in this character. The stout compact head of Type 1 of Tella jonna and the lean lax head of Irungu may form the extreme limits. All sorts of intermediates between these two exist. That a number of factors are concerned here is evident from the fact that different types of intermediates breed true. If pure strains happen to cross with another possessing the complimental allelomorph, compactness behaves as a pure recessive in the simple Mendelian ratio of 3 : 1. (Plates IV and V)

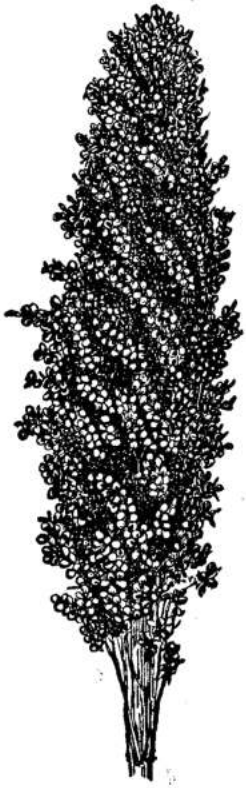
Table VIII.

Year.	Origin.	Reference	Character of the parent	Loose.	Compact.
1918-19	25	72 N	...	308	98
,,	,,	74 S	...	231	99
,,	,,	75 N	...	1239	424 Vide Plate IV.
,,	26	83 N	...	280	94
,,	32	99 N	...	233	63
,,	21	60 S	...	443	132
,,	40	116 S	Open	672	240
,,	G. 5	58 N	Loose	145	45 Vide Plate V.
,,	R 19	48 N	Loose	443	132
1919-20	99 N	227 S	Open	163	53

,,	,,	229 S	Open	114	50
,,	101 N	235 S	Close	...	Almost-(171.5)
,,	102 N	241 S	...	187	131
,,	,,	242 S	...	292	71
,,	60	215 S	Compact	...	All
,,	,,	216 S	Compact	...	All
,,	63	222 N	Open	223	108
			Total	4973	1740
			Expectation 3:1	5034	1678

PLATE IV. (Vide page 13)

Open.



Close.

(7) Color of Grains.

In 1919 it was noticed in selection 99 that some heads had a red tinge on the exposed portion of grains whilst others exhibited white grains. These were classified and the progeny was studied next year. Red segregates in the ratio of 3: 1. This is in accordance with the results obtained by R. J. D. Graham at Nagpur[1].

Table IX.

Year.	Origin.	Reference.	Character of the parent.	Red.	White.
1918—19	32	99 N	Dirty White	197	53
1919—20	99	248 S	Reddish White	67	21
,,	102	240 S	Do	141	37
,,	,,	242 S	Do	232	72
			Total...	637	183
			Expectation (3: 1)	615	205

While dealing with the color of the grains it may be mentioned that grain sorghum G. 5 had more reddish grains. When that was was sown, out of curiosity, it produced strangely enough, grains possessing different shades of red, yellow and white as shown in Plate VI. The figures were:—

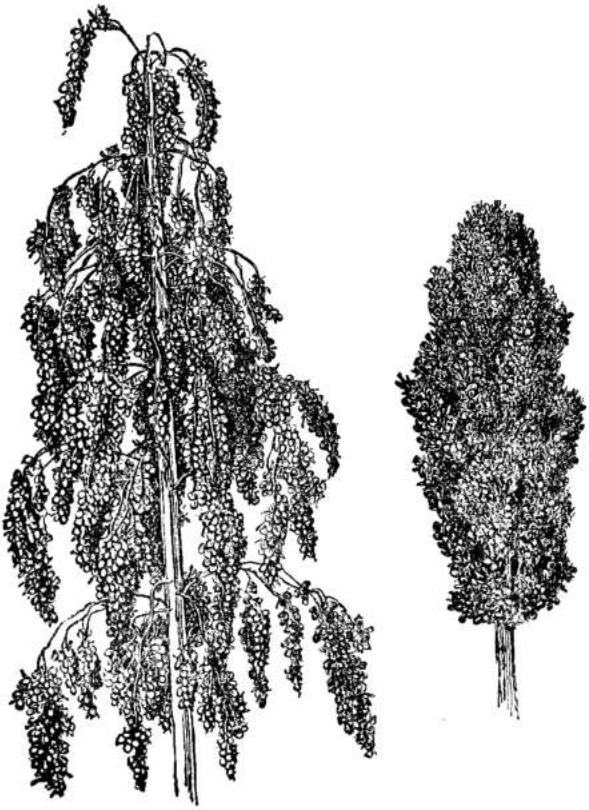
Plant 58	Deep red	58	(C of Plate VI.)
	Light red	14	(D do)
	Rose	42	(E do)
	Yellow & red blended	43	(A do)
	Yellow with dots	6	(G do)
	Pure Yellow	13	(F do)
	White	14	(B & G do)
,, 59	Red including all shades	125	
	Yellow ,, ,,	82	
	White	13	

(Plate VI has not been reproduced.)

Adding the figures in the two plots the ratio was Red: Yellow: White = 239: 144: 27.

1, Graham R. J. D. Loc. Cit.

PLATE V. (Vide page 13)



Open Close.

Summary.

The results may be summed up as follows:—

1. Sorghum flowers open between 1 and 8 A. M., the exact time varying with the atmospheric conditions prevailing on the day of opening.

2. A number of factors are concerned in the production and distribution of hairs on the glumes. Dense felting behaves as a dominant with regard to "no hairs." Such plants can be easily

detected by the hairs on the band above the node, long before they are in ears.

3. An inhibitory factor, which mendelises, is responsible for the non-development of black color on the glumes.

4. Red pigmentation over the neuters, wrinkled glumes, loose heads, short awns, and the red color of the grains, break up in the next generation in a simple 3 : 1 ratio.

Acknowledgments.

Thanks are due to Mr. G. R. Hilson, now Cotton Specialist, Coimbatore for the facilities given in conducting the work above described and for various suggestions made from time to time.

For the drawings, the writer is indebted to Mr. S. Subramania Iyer, Head Artist, Government Entomologist's Office.

(A Paper that won the Ramasastrulu—Munagala Prize, 1923.)

The power of Evil Thoughts.

The sky is clear. Now we see a small black cloud on the horizon. Soon it has covered the whole sky. Thunder peals! Lightning flashes! Death and destruction follows in the wake of the storm. So a bad thought rises in the heart of man. In the same way it develops. It arises without commotion, but soon it fills the heart. The passions burst forth like the bolts of lightning. Angry words are heard like the crashings of thunder. And as with the storm, damage is done that is hard to repair. How necessary is it therefore to watch over our thoughts!

Great Thoughts, 1923.